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OUR PRESENT KNOWLEDGE OF THE DISTRIBUTION AND IMPORTANCE OF SOME PARASITIC DISEASES OF SHEEP AND CATTLE IN THE UNITED STATES.

BY

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IMPORTANCE OF PARASITIC DISEASES.

The importance of diseases due to animal parasites is not generally appreciated. This is largely due to the fact that the diseases and the parasites are not well understood. The parasitic diseases with which people in general are familiar are those due to bacteria. It is understood that bacteria, though omnipresent, are very small, and that certain apparatus is necessary in order to see them. No such understanding exists in the case of the worm parasites, and since these do not intrude themselves on the attention of the casual observer it seems to be more or less assumed that these parasites are comparatively rare, that they are of importance only to the specialist or to persons geographically remote. As a matter of fact, parasites which are comparatively common and large enough to be readily seen may be easily overlooked unless looked for, and looked for intelligently.

One reason why people in this country fail to understand the nature and importance of parasites is that there are so few students of the subject in the United States. Not only are there few American specialists in this field, but our physicians and veterinarians pay less attention to this subject than do the European physicians and veterinarians. It follows, here as elsewhere, that where there is a lack of accurate information there is an abundance of inaccurate belief, among others a belief in the infrequency and harmlessness of parasitic infection. A feature which favors this condition of affairs is the fact that infection with worm parasites can hardly be detected in many cases on the basis of definite clinical symptoms, as bacterial diseases can, but depends for its detection on the findings of fecal, urine, blood, and sputum examinations, or even the examination of the flesh, as in the case of infection with trichinæ or certain bladder worms.

It is encouraging to note that while we are still far from a general appreciation of the importance of parasitic diseases, there is, nevertheless, a growing appreciation. In this country an increasing knowledge of this subject is to some extent merely our part of the growing

understanding of the world. The unusually large part which parasites play in the field of tropical medicine has compelled physicians and veterinarians everywhere to pay some attention to this allied branch of zoology. In our own country the scientific interest of such workers has been given point by our acquisition of Porto Rico and the Philippines, by the work against malaria and yellow fever, and by the educational campaign against the hookworm in the Southern States. The United States Department of Agriculture, the State experiment stations, and the farm and stock periodicals have insisted on the importance of the stomach and nodular worms of sheep until the farmer and stockman have become acquainted with them as facts, even if they still fail in many cases to know the things themselves.

These parasites which are to some extent known are but a small part of the total number which affect man and the domestic animals. The two hosts which are to be considered in this paper, the sheep and the cow, are afflicted by a large number of parasites. These parasites are external and internal. Some cause only a comparatively slight annoyance or physiological disturbance; others, unless interfered with, will kill every animal attacked by them. They include numerous species of protozoa (one-celled animals), trematodes (flukes), cestodes (tapeworms), nematodes (roundworms or threadworms), insects, and arachnids (mites and ticks). The Texas-fever parasite, *Piroplasma bigeminum*, is the most important protozoan parasite of cattle in this country. There are no protozoan parasites of sheep in the United States that are known to be of importance at present. Our cattle are infected with at least three flukes and our sheep with two; two of these are of known importance. Our cattle are infected with three larval and two adult tapeworms, and our sheep with three larval and four adult tapeworms. According to Ransom[1] (1911), the digestive tract of American sheep is infested with 22[2] nematodes and that of the cow with 12. Other nematodes infest the lungs, body cavity, etc. Numerous flies and lice attach themselves temporarily to our cattle and sheep, and some of the flies pass their larval stages within their bodies. A number of ticks attack American cattle and sheep, one of them being the carrier of the Texas-fever parasite of cattle, and there are a number of mites which cause the several varieties of scab and mange in the sheep and the cow.

Any one parasite may occur on or in an animal in such numbers or under such circumstances as to cause severe injury or, in many

[1] References to literature may be found in the bibliography at the end of this paper or in Bureau of Animal Industry Bulletin 39, "Index-Catalogue of Medical and Veterinary Zoology." Only references not appearing in the Index-Catalogue are given in the bibliography.

[2] A new species, bringing up this total to 23, has been discovered in Colorado sheep by the writer.

cases, death. Thus the Texas-fever parasite multiplies in the blood of cattle to a point where it often causes death. Liver flukes obstruct the flow of bile, destroy the liver tissue, and very commonly kill the infected animals. The gid parasite destroys the brain tissue and thereby injures the nervous mechanism to the point where the sheep is no longer able to eat and spends its time in a monotonous and continuous repetition of some automatic or reflex action until it dies of starvation or the cessation of some vital activity dependent on some injured brain part. Nematode parasites of the digestive tract of sheep frequently occur in large numbers. The writer has collected 3,915 stomach worms and 981 hookworms from one sheep and 4,350 stomach worms and 296 hookworms from another. There are often thousands of such small nematodes as *Strongyloides* in the sheep, and yet such an infection will be easily overlooked unless carefully searched for. As many as 60 to 80 grubs of the sheep gadfly, *Œstrus ovis*, have been taken from the head of a sheep. Such massive infections with grubs or nematodes can not fail to result in injury or even death. Even relatively light infections are apparently sufficient to cause the death of an animal under adverse weather conditions or during periods when food is scarce, while uninfected or less infected animals manage to survive.

DESIRABILITY OF A STUDY OF DISTRIBUTION.

It is highly desirable that we should know the distribution of a parasite. Knowing the distribution, we would have valuable data as to its economic importance. We would know whether it is of local or limited importance, or of general importance. With such knowledge the stockman would know what parasites were to be guarded against as being already in his neighborhood and what were to be guarded against in shipping in stock from other places. A fairly complete record of distribution would indicate foci of infection and awaken the interest of persons resident at such foci. Such a record is essential in campaigns of eradication, as we know from experience with the hookworm disease, sheep scab, and Texas fever, three of the best known of the diseases due to animal parasites. From a scientific standpoint such records would be valuable as showing whether the conditions necessary for a parasite's life cycle exist only in a restricted area or over practically the entire country.

When these things were known, certain lines of action previously impossible or not definitely indicated would become possible and definitely desirable. Knowing the distribution and economic importance of a parasite, we would know how much we might fairly emphasize the subject and to what localities an educational campaign should be directed. In this way the forces that would otherwise be wasted in a misdirected effort at points where a given parasite did

not exist would be conserved and expended over infected areas. Parasites that have not yet been distributed over the entire country could then be restricted to the places where they have a foothold, and in time eradicated from these places. From a scientific standpoint a knowledge of the distribution of a parasite would probably throw some light on its habits and its life history, and perhaps indicate a corresponding distribution of intermediate hosts or of other conditions requisite for the life cycle. This in turn would permit of outlining more adequate means of prophylaxis.

LACK OF DATA.

With such rare exceptions as in the case of Texas fever and sheep scab, which are matters of quarantine, hookworm disease of man, which is now a matter of special study and investigation under the Rockefeller fund, and the yellow-fever mosquito, which was investigated by Howard (1905) in connection with the yellow-fever work of the Public Health and Marine-Hospital Service, the study of the distribution of the parasites of man and the domestic animals in the United States has not been undertaken. One reason for this is that the data necessary for a satisfactory study are not yet available. The preliminary work of the amateur and professional collector, the contributor of short notes and records, has not been done. In fact, the amateur collector of parasites in this country is practically an unknown quantity, and the professional workers are few and, unfortunately for this purpose, concentrated largely in one place. Considerable material has been collected in the Government laboratories at Washington, some of it being sent in from outside places and thereby affording some data. The value of these data is often lessened by a possible or evident unreliability on the part of the collector, who is often not even an amateur in the best sense of the word, but merely the casual collector of a strange object which has caught the attention. Many of these outside records tell practically nothing about distribution, as the parasites were collected in the slaughterhouses at big packing centers, and the locality to which the infection should be referred is unknown. In our literature we have very few records made by specialists at universities, and of the limited records of the physicians, veterinarians, and experiment-station workers a large amount is casual, indefinite, or unreliable.

Nevertheless, in spite of the lack of such data as would serve to give a fairly complete statement of the distribution of a parasite, it is still desirable that a preliminary and necessarily incomplete statement be made. In the first place, such a preliminary statement furnishes a considerable incentive for additional records. Most persons would be willing to record the finding of a zoological specimen if they thought the record would serve any purpose, or would send it to

a specialist if they thought he could use it or would want it. The idea that the specimen is probably of no interest or value usually prevails and the matter ends there. The more common a specimen is to a collector, the less value or importance he will attach to it. Many do not know that records of occurrence are of real value, or appreciate that the fact that a species is common is apt to indicate that it is of economic importance. It is furthermore impossible for most persons to look up the scattered literature to see whether a species is recorded from a given locality, owing to the lack of literature, time, or inclination. When a preliminary statement of the distribution is available, it is easy to determine whether a parasite has been recorded from a given locality, and there is incentive to make such a record if it has not been made, or to fill gaps in the record from literature that has been overlooked. Conversely, such records of distribution serve as a guide in looking for parasites, since they show that a given parasite has been found at a given point and may be expected to occur there again, or that it has not been found and that the finding will be an addition to our knowledge. Incidentally it may be said that in this country many parasites, as well as many findings, would be new.

As an illustration of the utility of such a preliminary survey, we may take the work on the hookworm. With the preliminary records of Stiles (1902 hh, 1903 l, et al.) it was possible for various physicians to add intelligently to the records, thus mapping out the infected areas. Conversely, it led physicians to look for the hookworm in those States from which it was recorded or where the records indicated that it would be found, for such records indicate possibilities and probabilities in addition to showing known facts.

THE PRESENT STUDY.

It is almost impossible at the present time for anyone, even though in close touch with the parasite work of this country, to say out of hand whether a given parasite occurs in a given State, or to give the range of a parasite, or name the parasite fauna of a State, even for parasites of considerable importance. It would be a work of years to get such a statement for all the parasites of recognized economic importance. It is hoped that the present paper will serve as a nucleus for such a work, and that those who come in contact with parasites may be induced to group new records around these. This paper is limited in its scope to nine of our more important and representative parasites. Even within these limits it is admittedly incomplete. The papers from which it is compiled in part are scattered and unrelated for the most part, and it is out of the question to get hold of all the papers that would add to our knowledge of the distribution of these parasites. This incompleteness is itself an additional reason

for making this preliminary record. It should lead to filling the gaps which are due to the writer's failure to take cognizance of published records, and those which are due to an actual lack of records, much sooner than would be the case if this compilation were not made. It is hoped that in time sufficient data will be available to permit of a biological survey such as is possible with our bird, mammal, or insect fauna. Of course, such a survey would be very definitely limited and modified by the dominating condition of parasitism.

THE MAPS.

It is essential in work of this sort that the distribution be graphically shown by the use of maps. At the same time, maps based on inadequate data must be inaccurate, a fact which must be kept in mind in using these maps. For one thing, it is out of the question in all cases to take cognizance of small uninfected areas which care or accident has kept free from infection although surrounded by infected areas. For the most part it is also impossible to indicate on a map those areas which are uninfected for the reason that the host animal in question does not exist within that area. Finally, a sweeping statement to the effect that a parasite causes severe loss over an entire State must be transferred to the map in symbols indicating that the entire State is infected, whereas there might perhaps be fewer counties infected than in some other State where more careful work and more adequate and exact data have shown only a part of the State to be infected. The nature of our data from any given locality is indicated as exactly as is possible with the use of a limited number of symbols. Where a map record is not referred to in the text the record has usually been made from the official letter files of the bureau.

DISTRIBUTION OF SOME SHEEP AND CATTLE PARASITES.

The parasites which have been selected for study as regards their distribution in the United States include representatives of the various parasitic groups. They are also some of the best known and most important parasites in their groups, as far as this country is concerned. Some of them are apparently spreading, others are being eradicated, while it is impossible to tell about others, owing to the lack of data covering their distribution in the past.

The parasites in question are: *Piroplasma bigeminum*, the protozoan which causes Texas fever in cattle; *Fasciola hepatica* and *F. magna*, the flukes responsible for liver rot in sheep and cattle; *Multiceps multiceps*, the larval tapeworm causing gid in sheep; *Thysanosoma actinioides*, the fringed tapeworm of the bile ducts and intestines of sheep; *Hæmonchus contortus*, the stomach worm of sheep;

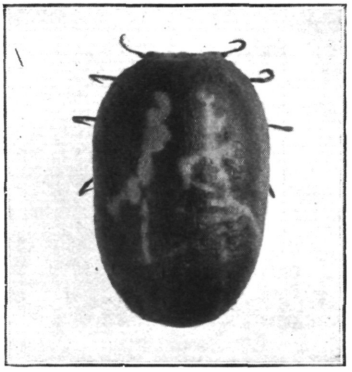

FIG. 1.—FULL-GROWN FEMALE TICK (MARGAROPUS ANNULATUS), ENGORGED AND READY TO DROP TO GROUND AND DEPOSIT EGGS.

(From Farmers' Bulletin 378.)

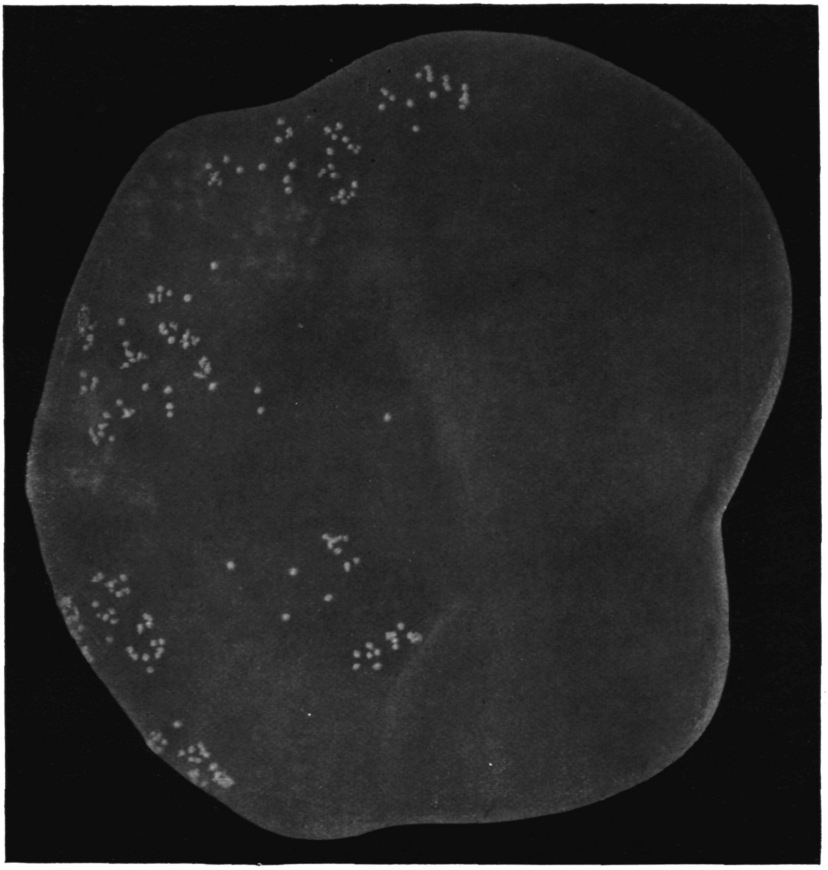

FIG. 2.—THE GID PARASITE (MULTICEPS MULTICEPS) FROM BRAIN OF SHEEP.

(From Bureau of Animal Industry Circular 165.)

Œsophagostomum columbianum, the nodular worm, a nematode causing nodular disease or "knotty guts" in sheep; *Œstrus ovis*, the sheep gadfly, which passes its larval stage in the nostrils and frontal sinuses of the sheep under the name of "grub in the head;" and *Psoroptes communis ovis*, the mite which causes sheep scab or scabies.

Piroplasma bigeminum.

Smith (1889 b) first recognized that the intracorpuscular blood parasites (fig. 45) which occur in the blood of cattle affected with Texas fever were protozoa. An extensive description of the disease and its parasite was given by Smith and Kilborne (1893) in a work which is now a classic and rated as one of the most important in the field of protozoology. They proposed the name *Pyrosoma bigeminum*, but the generic name *Pyrosoma* was preoccupied, as was the name *Apiosoma* proposed in place of it by Wandolleck. The name proposed by Patton, *Piroplasma*, is commonly accepted, though there is a possibility that the parasite is generically identical with forms included in the genus *Babesia*, and that this should be the generic name. This, however, has not yet been demonstrated. Theiler (1910) notes that Smith and Kilborne distinguished two forms of the parasite in the blood and believes that the small coccuslike forms at the margin of the blood corpuscle are not parts of the life cycle of the piriform parasite, but represent a different parasite, for which he proposes the new generic and specific name *Anaplasma marginale*. According to this view, the Texas fever of this country is the result of a mixed infection. It is as yet too early to pass judgment on Theiler's claims.

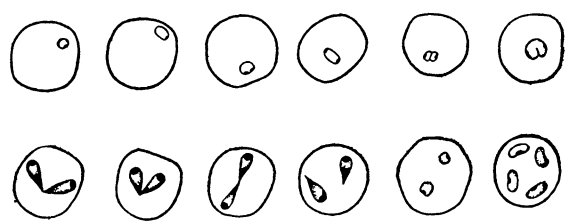

FIG. 45.—Texas-fever parasites (*Piroplasma bigeminum*) in the blood corpuscles of an ox. Enlarged. (After Laveran and Nicolle.)

When *Piroplasma bigeminum* is conveyed to the blood of cattle by the bite of the tick *Margaropus annulatus* (Pl. XXXV, fig. 1) (this tick is also known by the name *Boophilus annulatus*), the parasite multiplies in the blood and attacks the red blood cells. The red blood cells being destroyed, the coloring matter of the blood is excreted by the kidneys and causes the red color of the urine, which gives this disease the name "red water." The disease is accompanied by a high fever, and the animal becomes thin. Mohler (1905) states that death occurs in from 10 per cent of the chronic to 90 per cent of the acute cases. The chronic cases are found among

southern cattle which are infested with the fever tick from birth or in cases usually appearing in late autumn or early winter; acute cases occur among cattle not naturally immune which are subjected to heavy infestation, usually in summer.

The great losses due to Texas fever, the ease with which the disease can be recognized clinically, and the fact that it depends for its spread upon a specific carrier, the Texas fever tick, and can therefore be prevented from spreading by such a simple routine procedure as dipping and thereby destroying the ticks, early led to this disease becoming a subject of quarantine. As a result it was soon confined to the territory in which it was properly enzootic, and the distribution of the disease can be found at once by reference to the quarantine lines which separate the infected southern part of the United States from the uninfected northern part. (See fig. 46.) As will be seen by the map, there are a few small infected areas just north of the principal infected area and surrounded by uninfected territory. Along the northern edge of the quarantined area the disease is being stamped out as rapidly as possible under the direction of State and Federal authorities, especial attention being paid to the eradication of the tick. As soon as areas south of the line and bordering on it are tick free the line is moved south of these areas and the restrictions on shipment imposed by the quarantine are removed. These restrictions require that shipments from January 31 to November 1 be made only under certain specified conditions.

Previous to the establishment of the quarantine line no State in the Union could be considered free from Texas fever. Practically every shipment of southern cattle left the disease among the cattle of the States through which they were shipped. This was due to the fact that infected ticks dropped off in transit, and larvæ hatching from the eggs laid by the engorged females attached to northern cattle and thereby conveyed to them the *Piroplasma bigeminum*. Salmon (1885), in the first report of the Bureau of Animal Industry, records the establishment of the boundary of the permanently infected region in the United States east of the Mississippi River. The boundary line as thus established extended across Virginia, North Carolina, the northern end of Georgia, and Tennessee. On July 3, 1889, the first Federal quarantine on account of Texas fever was declared in an order issued by the Secretary of Agriculture, the quarantine line extending across Arkansas, the Indian Territory, and Texas. The line was altered somewhat by Secretary Rusk's order of February 24, 1890. On February 5, 1891, the quarantine line, with some alterations, was extended east along the southern boundary of Kentucky and across Virginia to the Atlantic Ocean. The line was finally established across California, and so from coast to coast, by Secretary Morton's order of February 5, 1895.

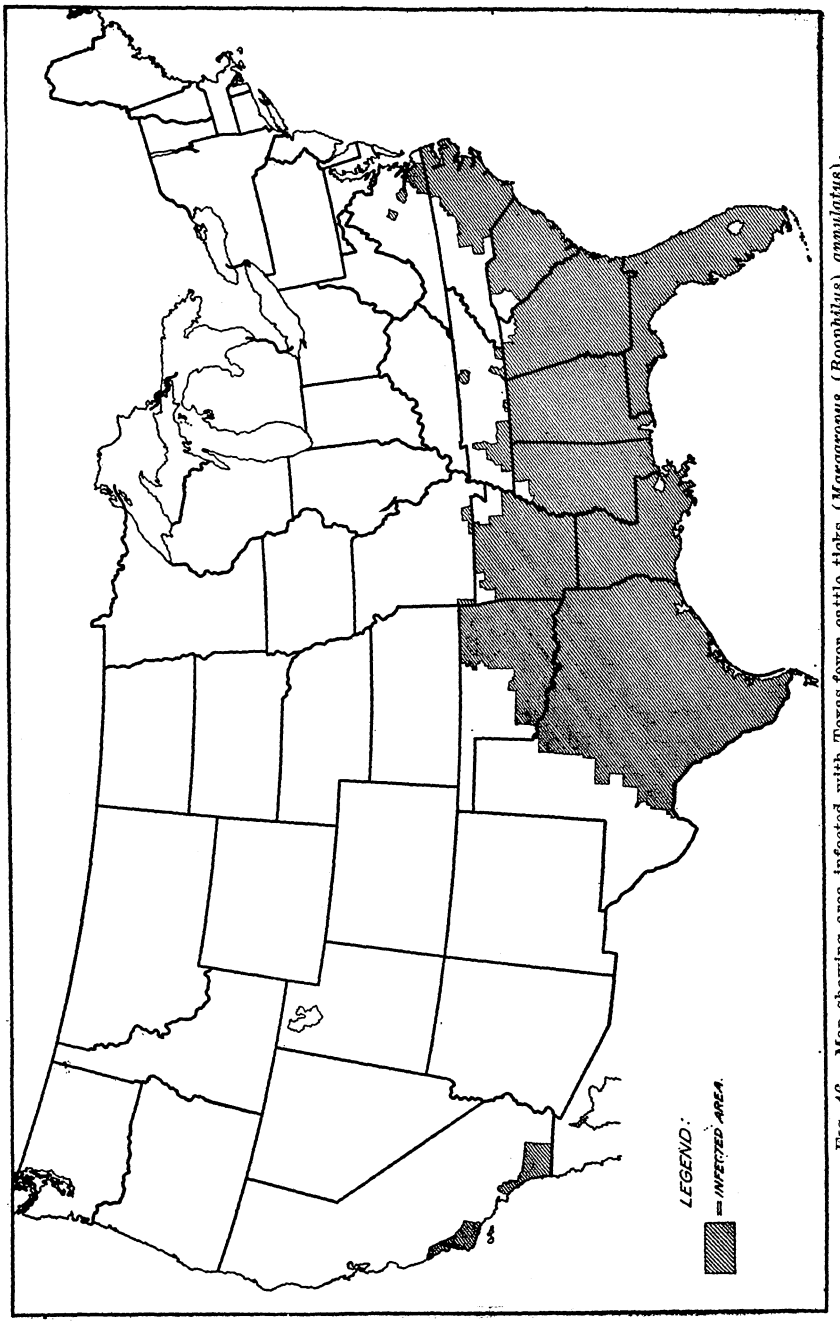

FIG. 46.—Map showing area infected with Texas-fever cattle ticks (*Margaropus* (*Boophilus*) *annulatus*).

Mohler (1905) says that the estimated loss to the infected district from Texas fever is $40,000,000 per annum, with an additional $23,250,000 loss in lowered assets. These figures are sufficient to show the magnitude and importance of this disease. It limits the southern stockman and farmer in disposing of their stock, in shipping in cattle to improve their herds, and in holding fairs and exhibitions of stock.

Fasciola hepatica.

This is the common liver fluke of sheep. It has been found in sheep in practically all countries where sheep are kept and has been a source of considerable loss for centuries. It is a flat worm (fig. 47, *a*), commonly 1 or 2 inches long, and has a complicated life history. The life cycle can only be completed after passing certain stages in the bodies of certain snails. At the end of the development period within the snail a larval form known as a cercaria is produced. This leaves the body of the snail, attaches to a blade of grass and encysts. When swallowed by a sheep or cow the cyst is digested and the parasite makes its way to the liver. The adult worm produces vast numbers of eggs which are passed with the feces of the host. In such of these as fall or are washed into bodies of water there develops an embryonic form which escapes from the egg and infests suitable snails.

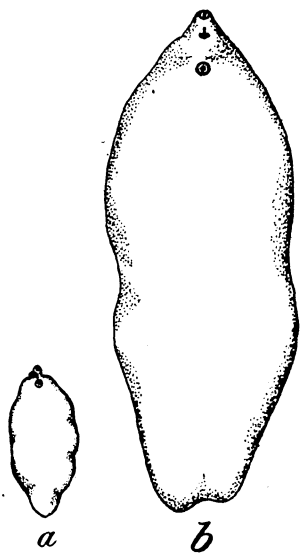

FIG. 47.—*a*, The common liver fluke (*Fasciola hepatica*). *b*, The large American fluke (*Fasciola magna*). Natural size. (After Bureau of Animal Industry Bulletin 19.)

The infected sheep may at first get fatter, then they become thin, feeble, and anemic, many of the sheep dying. The bile ducts are obstructed, their walls become thickened and hardened, and the liver atrophies. Bad effects are less noticeable in cattle than in sheep. In the spring and early summer the flukes leave the liver, only the remaining scars and other lesions indicating where they were located.

In this country the liver fluke has become fairly well established along parts of the Pacific, the Gulf, and the eastern Atlantic coasts (fig. 48). From the coast it works inland along the river valleys. This distribution is precisely what would be expected in the case of a parasite requiring a snail for an intermediate host. It does not seem to have become established at any remote inland points, although

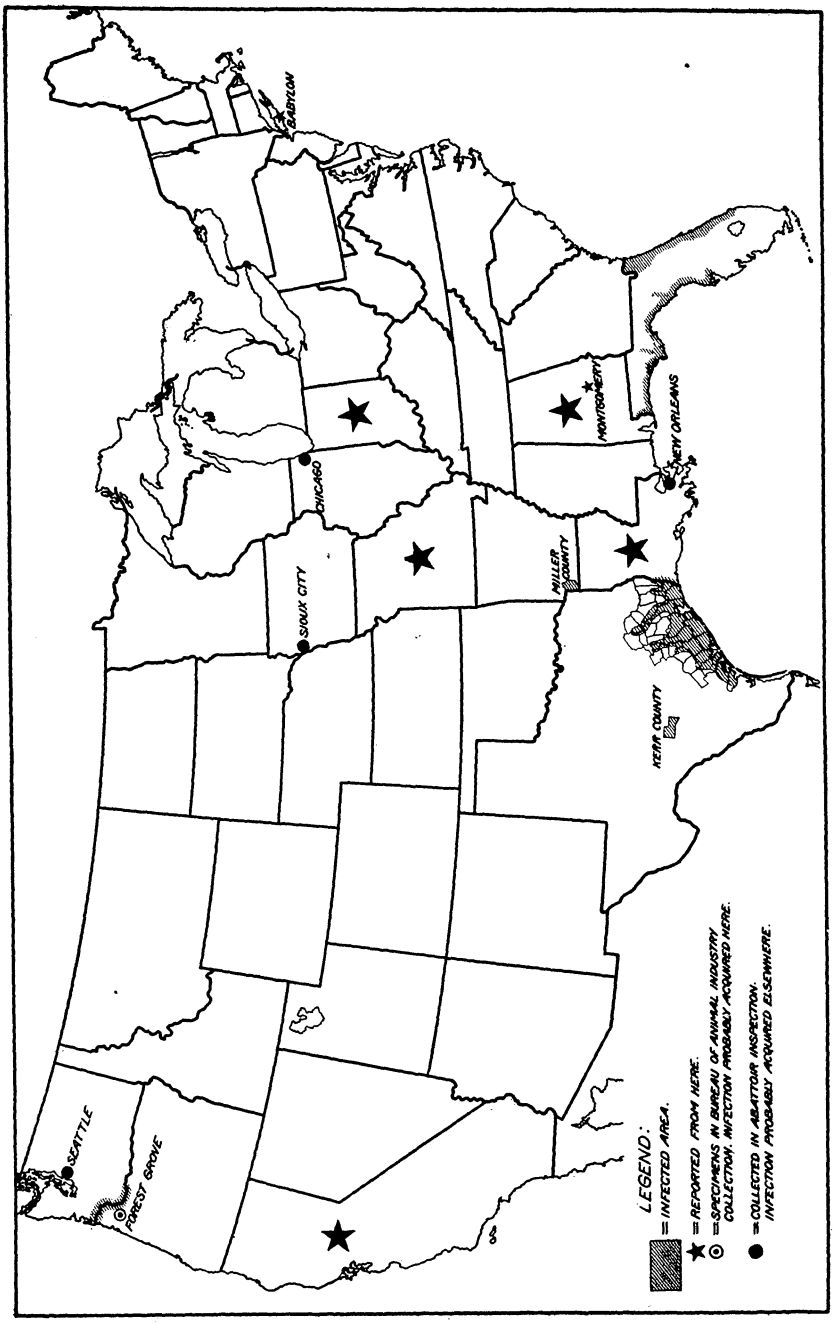

FIG. 48.—Map showing infection with the common liver fluke (*Fasciola hepatica*).

it is occasionally found in abattoir inspection at Sioux City and Chicago. In such cases the host animal has been shipped in, presumably, from the regions which are here shown to be infected.

The parasite is established on the west coast. Gordon (1883), in the Tenth United States Census Reports for 1880, quotes a letter from a sheepman in California, who says: "Our diseases are fluke, scab, water on the brain, and foot rot; the first is the most fatal." Curtice (1890 c) states that flukes have been seen in California by Prof. E. C. Stearnes, of the Smithsonian Institution. Stiles (1902 pp) notes that 5 per cent of the sheep along the Columbia River bottom were infected with *F. hepatica*, while 75 per cent of the sheep along the western slope of the Cascades in Oregon were infected. The lesser infection in the first case is believed to be due to the carp in the Willamette and Columbia Rivers eating the cystic stage of the fluke on the grass and presumably eating the snail also. The parasite collection of this laboratory has specimens of *F. hepatica* collected from the cow at Forest Grove, Oreg., in 1892, and in 1905 Dr. Elda R. Walker, of the University of Nebraska, told the writer of having known of cases of fluke in sheep at Forest Grove, the flukes being believed by the owner of the sheep to be leeches which had been swallowed in drinking. This is a rather widespread belief. Stiles (1902 pp) notes the occurrence of this parasite at Ridgefield, Wash., and the parasite collection here has specimens collected from the sheep at Lake Cushman in 1904, and some collected from the goat, probably in abattoir inspection, at Seattle in 1905.

The parasite has been established in the Gulf States for over 30 years. Gordon (1883), in discussing the diseases of sheep in Texas, writes: "A flockmaster of San Saba County reports in 1877 a loss of 1,198 sheep out of 1,515 by liver rot." Detmers (1883) says: "This parasite occurs frequently only on the low and level lands near the Gulf. * * * In comparatively rare instances the flukeworm * * * also occurs in other parts of Texas—for instance * * * in Kerr County." This was written before *Fasciola magna* had been recognized as an American parasite, and Detmers was undoubtedly dealing with mixed infections involving both species of flukes, as Francis (1891 c) records both from Texas and gives a map showing the area over which the mixed infection occurs. Of *F. hepatica*, Francis states: "This well-known parasite occurs in the livers of cattle, sheep, and goats of Texas in sufficient numbers to cause great damage. The portion of the State permanently infected consists of the coast counties and river bottoms." Stiles (1901 t) notes the finding of *F. hepatica* in two steers in Harris County. Francis (1891 c), in his map showing the distribution of *F. hepatica* and *magna*, figures a part of the coast region of Louisiana as infected territory.

Wheeler (1894) says of *F. hepatica:*

> This platyhelminth is one of the greatest enemies to the successful rearing of sheep in this whole southern country. Our cattle are likewise the hosts of these worms. * * * I have not been able to observe any difference in the general health of Texas and native cattle and in extent to which these worms prevail in their livers. * * * During the year 1891 I condemned about 2,500 fluky beef and cow livers. Valued at 40 cents a piece, this would amount to $1,900 in livers alone. * * * I did not discover over 50 calf livers fluky during the same period.

This was at the New Orleans abattoir. Later, Wheeler (1896) gives a record of the inspection work at this abattoir for two months, from which it appears that during that period 556 livers and 20 lungs of cattle, sheep, and goats were condemned as fluky.

Cary (1897) writes:

> In Alabama and in most of the Southern States it is observed most frequently in the liver ducts of cattle. This is due to the fact that few sheep are bred in the South. The writer has observed these flukes in the pig in one case at the Montgomery slaughterhouse.

Bitting (1895) records this parasite from Florida along the coast region. He says that nearly all cattle in the infected area have fluke and that there is considerable loss, especially among young animals. There are no sheep in the infected area. He gives a map showing the location of this area. There do not appear to be any records of the parasite from Mississippi, but an inspection of the map indicates that the infection which occurs in Texas and Louisiana to the west, and in Alabama and Florida to the east, under practically the same geographic and climatic conditions, is probably present in Mississippi also. Ward (1895) says that *F. hepatica* is exceedingly common in Arkansas. I am unable to find any authority for this statement other than the fact that Francis (1891 c) indicates the southwest corner of Arkansas as part of the territory with a mixed infection. Dinwiddie (1892 b) states that he has never seen a fluke in the sheep in Arkansas, and the fluke which he reports from cattle is *F. magna.*

Dr. Luckey writes me under date of March 2, 1911:

> Upon one occasion several years ago I found a number of cattle in the lowlands of southeast Missouri heavily infested with *Fasciola hepatica.* This is not generally prevalent over the State.

An examination of the maps, together with the fact that the fluke was in cattle, indicates that closer examination would probably have shown this to be *F. magna.*

Along the eastern Atlantic coast we have the infection already noted from Florida by Bitting (1895). Aside from this, there is only Stewart's (1882) record of liver fluke in Southdown sheep at Babylon, Long Island, and in Cotswold, Leicester, and native sheep, presumably at the same place.

As to the interior of the country, it has already been noted that the parasite has been found in abattoir inspection at Sioux City and Chicago, the infection undoubtedly originating elsewhere. That this is true of Sioux City seems the more likely from the report of Niles (1897), who says:

> After looking over the literature on the subject, noting the results of several years' personal observations, and gathering as much information as possible from other observers, it can be said that the liver fluke * * * has not been recognized in Iowa.

Of Indiana, Craig and Bitting say:

> The liver fluke is of very rare occurrence in this State. As far as known to the writer only six flocks have been affected in the past ten years and in these the affection was brought onto them from the southwest. There is no fear of permanent infection of our pasture.

Luckey (1908) implies that this parasite is present in Missouri, but does not definitely say that it is.

It is evident from the foregoing that this parasite is of importance only on the Pacific coast and in the Gulf States. So far it does not seem to have established itself in the interior of the country, although it seems likely that there are places where favorable conditions for its establishment could be found. The data already given show that it is capable of doing considerable damage in those places where it has already got a foothold.

Fasciola magna.

This fluke (fig. 47, *b*), known as the large American fluke, may attain a length of 4 inches. It is commonly recorded from the cow in this country, but it has been recorded from a number of species of the Bovidæ. It has been found in the sheep in Italy in 1874–75 by Bassi, according to Railliet (1895), and the parasite collection of this laboratory has some specimens collected in January, 1906, from sheep at Hillsdale, Mich., which Dr. Ransom determined as *F. magna*. The sheep appear to have been shipped in from the State of Washington. Quite a number of sheep died, apparently from this parasite, and the Michigan sheepmen, who were feeding western lambs, were very much worried. This parasite was sent in to this laboratory by Dr. Ketchum, of the St. Paul meat-inspection station, in the summer of the same year, with the report that it had been collected from the sheep.

The life history and the intermediate hosts of this parasite are unknown. From the close relation of this fluke and the common liver fluke of sheep, and from the fact that the infected range of the two forms is very nearly the same, cattle frequently being infected with both flukes at the same time, it is probable that the life history of the two flukes will be found very similar and the intermediate hosts perhaps the same.

The occurrence of the large American fluke on the Pacific coast is a matter of speculation at present. As has just been noted, the sheep at Hillsdale, Mich., which were infected with this parasite appear to have been infected in Washington, but the records were not positive on this point. Curtice (1891 b) diagnosed a case of fluke disease in dairy cattle in Marin County, Cal. The diagnosis is made from a letter that clearly describes the fluke. Curtice states that while investigating animal parasites on the Pacific coast and in Texas, he found flukes in various localities. According to Stiles (1894), Dr. Curtice has stated that the flukes in the case noted were *F. magna*. The present writer is in doubt on this point. The flukes are stated to have been an inch long. They were in a State where fluke occurs in sheep, and the fluke which is known from the Pacific coast is *F. hepatica*.

The area with the greatest amount of infection is found in Arkansas and in the coast region and river valleys of Texas. (See fig. 49.) Francis (1891 c) states that he saw the parasite in Texas three years previous to 1891. Curtice (1887) recorded what he termed *Distoma hepaticum* (*Fasciola hepatica*) from the liver and lungs of Kansas cattle. Stiles (1894) says that Curtice has since told him that the parasites were really *F. magna*. It is quite as likely that Murray (1882) was dealing with *F. magna*, or with this and *F. hepatica*, in his report of *Distoma hepaticum* found in the lungs of Texas cattle at the Detroit slaughterhouses, as that he was dealing with *F. hepatica* alone.

Francis (1891 c), in his discussion of the large fluke, described it as a new species under the name of *Distomum texanicum*. Hassall (1891 a and 1891 c), in two articles which antedate that of Francis, had already named this *Fasciola carnosa*, and then changed this to *F. americana*, because the specific name *carnosa* was already preoccupied. This fluke had previously been named *Distomum magnum* by Bassi (1875 b), which name had been corrected to *Fasciola magna* by Stiles (1894).

Hassall (1891 a) had figured his specimen of *Fasciola carnosa*, and the figure is labeled " from liver of a Colorado steer." Stiles (1894) lists as part of his material " several specimens collected by Dr. Curtice at Colorado Springs (Hassall's type-specimens of *Fasciola carnosa* seu *americana*)." There are a number of reasons for thinking that this parasite has no foothold in Colorado, and it seems quite probable that the infected animal had come to Colorado from Texas or Indian Territory, the parasite occurring in cattle in Indian Territory, according to Dinwiddie (1892 b).

It seems uncertain whether the fluke has established itself in Kansas. We have the record of Curtice (1887), who says that " 3 out of a herd of 12 from Kansas were found to be infected with flukes," which

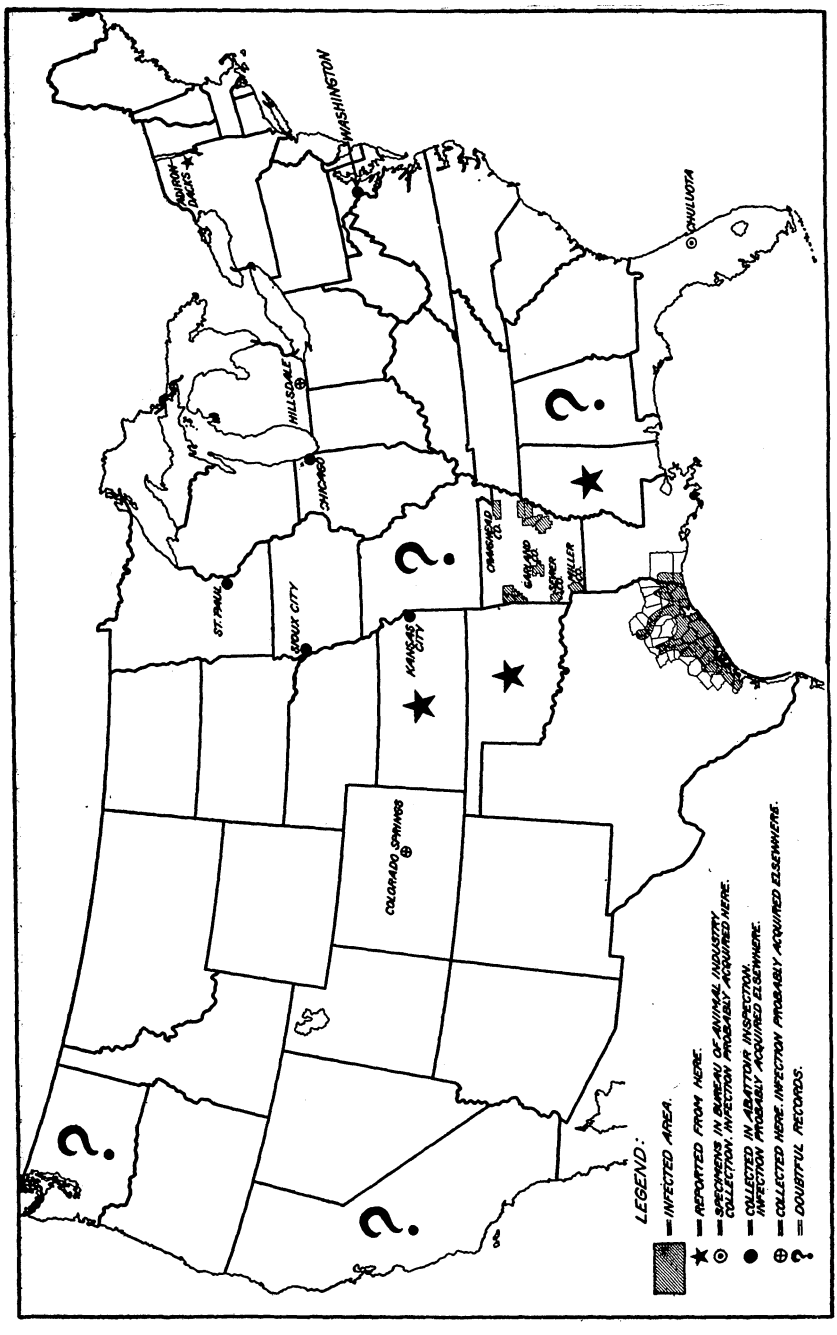

FIG. 49.—Map showing infection with the large American fluke (*Fasciola magna*).

flukes Dr. Curtice later said were *F. magna*, according to Stiles (1894). The parasite collection here has specimens collected from *Bos taurus* in Kansas in 1892. It is nevertheless possible that the infected animals became infected in Texas or Indian Territory (now part of Oklahoma).

Arkansas rivals Texas in the extent of infection with this fluke. Dinwiddie (1890) reported that 90 per cent of all the cattle on certain ranges in St. Francis and Lee Counties were infected. Later, Dinwiddie (1892 a) reported that the fluke infection was found in 11 counties in regions corresponding more or less closely with overflow districts along the rivers.

The fluke occurs in Louisiana, according to the map published by Francis (1891 c). A fluke 3 inches long and 1 inch wide was collected by G. V. Young from the liver of a deer at Waverley, Miss., and determined by Osborn (1890 a) as a species of *Distoma* other than the common liver fluke of sheep. This was undoubtedly *F. magna*. Cary (1897) states that in Alabama *F. hepatica* occurs mostly in cattle. He says nothing of *F. magna*, but it is likely that part of the flukes found in Alabama cattle are this species. Similarly, Bitting (1895) records only *F. hepatica* from cattle in Florida, but some specimens collected by Mr. Mills from the deer in Florida and sent in to this laboratory are *F. magna*, and it is quite likely that this is as common in Florida as is *F. hepatica*, and perhaps more common. There is nothing to indicate that Bitting's determination is more than a casual determination, and it would not be difficult to confuse the two flukes. It is furthermore true that *F. magna* is in general a cattle fluke, just as *F. hepatica* is in general a sheep fluke. It has already been noted that the flukes found by Dr. Luckey in southeastern Missouri, and hence near the known infected area in Arkansas, were probably *F. magna* rather than *F. hepatica*.

Outside of the Gulf region the records are inconclusive. Stiles and Hassall (1894 d) record a specimen from the Virginia deer in the Adirondack region of New York. Stiles (1894 c) states that it occurs in Iowa or has been found there. He gives a reference to Osborn (1890 a), but it appears from an examination of this record that, although Osborn was writing from Iowa, the flukes were collected in Mississippi, as noted earlier in this article. The only records I find from Iowa are specimens collected in abattoir inspection in 1907. Niles's (1897) statement of his failure to find the liver fluke in Iowa may be taken to cover *F. magna* as well as *F. hepatica*.

F. magna has been frequently collected in abattoir inspection. It was collected in the District of Columbia by Dr. Hassall in 1893 from a steer said to be from Texas. The parasite collection of this laboratory has a number of specimens collected in the Chicago abattoirs, some others from Sioux City, and some from St. Paul.

This fluke has been found in a number of American Bovidæ, and it is possible that the parasite is a native of this country. Stiles (1895 l) has suggested this, and also the alternative possibility that this fluke is a species which has developed from *Fasciola hepatica* since the introduction of the latter into this country. The earliest record of this parasite which I have found is that of Stewart (1882), who prints a drawing "from nature" of a fluke collected from the liver of a deer in 1874–75. The drawing is said to be reduced one-half and is 3.85 centimeters long. There is no doubt that this fluke, 7.7 centimeters long, is *F. magna.*

Ward (1895) says of this parasite: "In importance it stands hardly second to *F. hepatica.*"

Stiles (1898 a) says:

> The large American fluke appears to be more frequent in this country than the so-called common liver fluke, although this opinion is the result of general impression from abattoir inspection rather than a view based upon actual statistics. * * * Fortunately this species (so far as known) does not occur in sheep, and on that account it must be looked upon as of less importance than the common fluke.

As the writer has already noted, this species had been found in the sheep in Europe and has since been found in the sheep in this country. It seems to be rather rare in the sheep, which would perhaps be an argument against the hypothesis suggested by Stiles (1895 l) that this was a rather recently evolved species originating from *F. hepatica* since the importation of that form into the United States with domestic stock. It does not seem likely that a recently evolved species would so nearly forsake the normal host to which centuries of parasitism had accustomed it.

Generally speaking, this fluke does not seem to make the impression on the health of cattle that *F. hepatica* does on the health of sheep. Consequently the loss is less frequently noted in terms of dead cattle and oftener in the lesser losses resulting from loss of weight, condemnation of infected livers, and the like.

Multiceps multiceps.

This parasite, the popular name of which is the gid bladderworm, is generally known as *Cœnurus cerebralis*, but the writer (Hall, 1910 a) has shown that the correct name is *Multiceps multiceps.* It occurs in the central nervous system of the sheep and cow and also in that of a number of other animals. It is found in the brain in the great majority of cases, and looks like a fish bladder filled with water (Pl. XXXV, fig. 2). This bladder varies in size, but at the time of the host animal's death it commonly ranges from the size of a nut to that of a hen's egg. It is sometimes larger, and the one shown

in Plate XXXV contained 80 cubic centimeters of fluid. On the walls of the bladder are a number of scolices or tapeworm heads, sometimes hundreds. When the bladder is eaten by a dog—and it is essential that a dog, coyote (see Hall, 1911), or perhaps some other suitable carnivore eat the bladder if the parasite is to undergo further development—the bladder walls are digested in the dog's stomach and the heads pass to the intestine, where they become the heads of a corresponding number of tapeworms. Numerous tapeworm segments form back of these heads, ultimately resulting in the development of tapeworms 2 or 3 feet long (fig. 50). Thousands of very small eggs are produced by the worms and pass out in the feces of the dog, sometimes inclosed in the terminal segments as these break off, and sometimes freed from the segments when these have ruptured and scattered the eggs throughout the feces. These eggs are released from the feces by rains and in this way are splashed onto plants which are eaten by the sheep, or washed into pools of water from which the sheep drink. When the eggs are taken into the stomach of the sheep the shell digests, thereby releasing a small embryo armed with six hooks. The embryo bores its way through the walls of the digestive tract and into the blood vessels. It is then swept around in the blood current till it lodges. If it lodges outside of the central nervous system, the parasite starts to grow, but aborts in a short time. In the central nervous system the parasite usually wanders around through the brain tissue for a time and then grows to form the bladderworm already described.

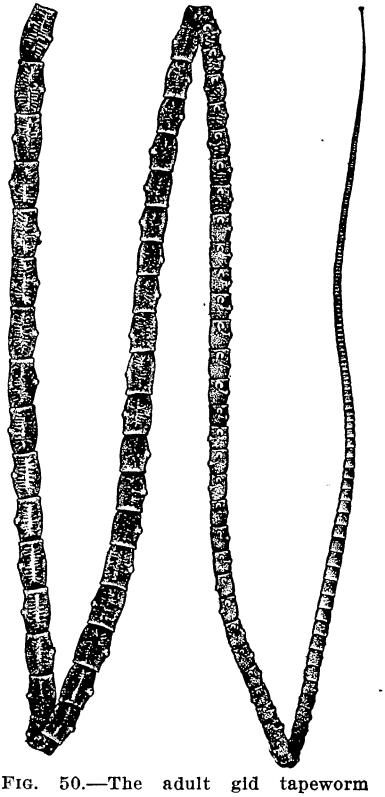

FIG. 50.—The adult gid tapeworm (*Multiceps multiceps*) from the intestine of the dog. Natural size. (From Bureau of Animal Industry Circular 165.)

The wanderings of the parasite in the brain cause a certain degree of fever and restlessness, which is usually overlooked. If the number of parasites is very large the sheep may die at this time. Postmortem will then show numerous curving channels on the brain, due to the wanderings of the embryos. Usually the symptoms abate and there is no further indication of the presence of the parasite until it has grown to the point where the heads form on the bladder and set

up the symptoms characteristic of the last stages of gid by projecting out of the bladder and into the brain. As a result of the irritation due to these heads, which are armed with hooks, and of the pressure due to the growth of this large parasite within the skull, the sheep displays symptoms indicative of the derangement of the central nervous system, such as walking in a circle or constantly repeating some other meaningless automatic action, constant carriage of the head to one side, ceasing to eat, blindness, and the like. Unless the parasite is removed or destroyed by surgical intervention, the infected sheep invariably dies.

The writer (Hall, 1910 a) has already recorded the distribution of this parasite for the world. In the United States the permanently infected area is in northern Montana and is about 400 miles long and in places 200 miles wide (fig. 51). There was a small infected area in New York in 1909 and in Iowa in 1910. The parasite has been reported, apparently correctly, from Ohio, Illinois, Michigan, Missouri, Kansas, Indian Territory, and Nevada, and there are doubtful records from Utah, Colorado, and Tennessee. There is a possibility that small infected areas occur in these States, but so far it has been impossible to locate any. It seems likely that most of the cases in these States were imported from abroad or from the infected area in Montana. A hasty investigation, by the writer, of conditions in Idaho, Nevada, Utah, Colorado, and Wyoming in the spring of 1910 failed to disclose any evidence that the disease had a foothold in those States.

Evidence obtained by the writer in an investigation in Montana indicates that the losses from this disease amount to at least $10,000 in some years. It is difficult to determine the entire loss, as the disease is confused by the sheep men with other diseases, such as loco and grub in the head, notwithstanding the fact that the disease has existed in this State for over 20 years. The gid disease is of especial economic importance in that it is always fatal to the animal attacked, unless the animal is saved by a successful operation. It has been a scourge to the flocks of Europe for centuries, and it is highly desirable that it be kept within the area now known to be infected and eradicated from that area as soon as possible in order to remove the menace of its presence from the United States.

Thysanosoma actinioides.

This tapeworm is commonly known as the fringed tapeworm, for the reason that the posterior border of each segment has a fringe of projections (fig. 52). These can be easily observed when the parasite is put in water, as the fringe floats out from the segment. The worm is sometimes a foot (30 centimeters) long. Very young stages consisting of little more than the head have been found by Curtice

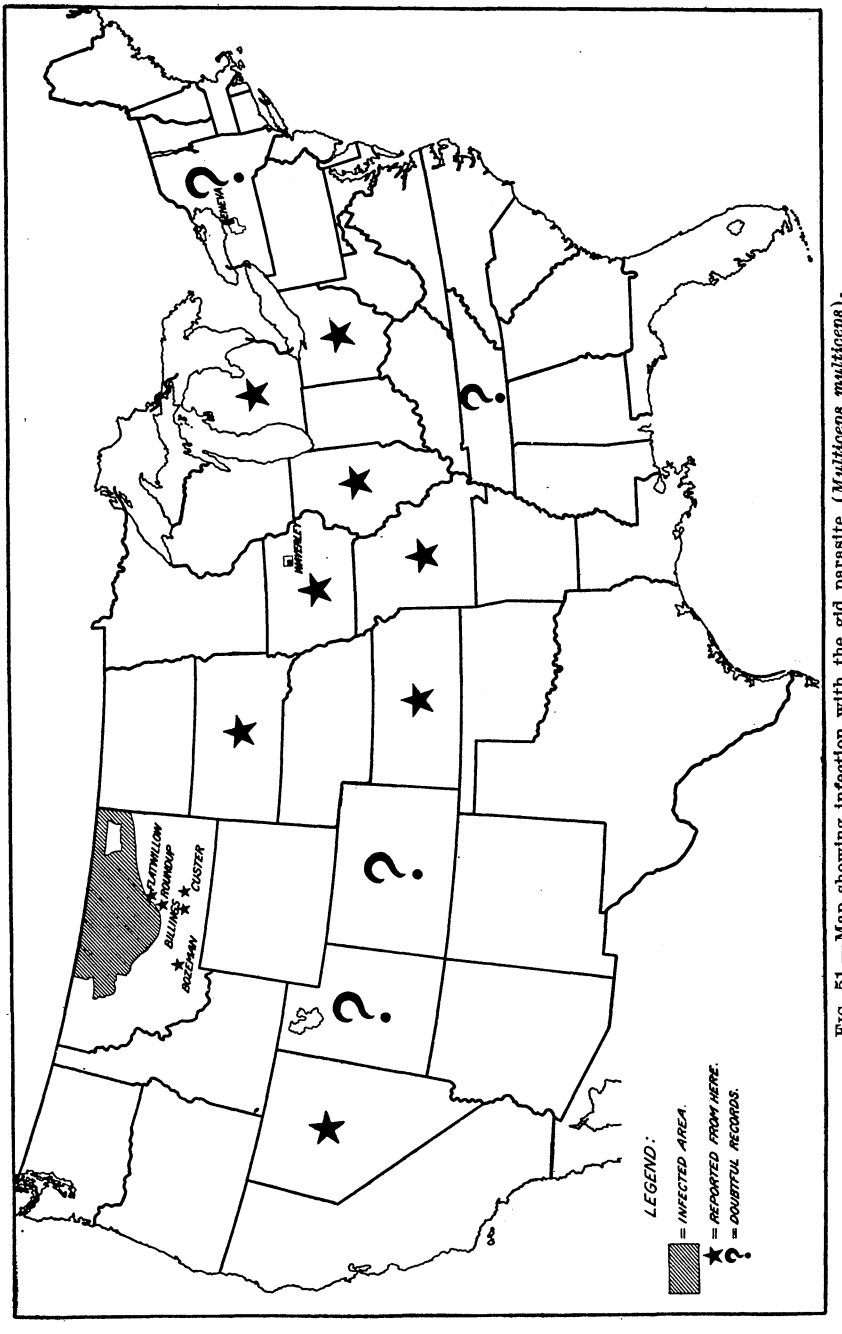

FIG. 51.—Map showing infection with the gid parasite (*Multiceps multiceps*).

(1889 and 1890 c). From these to the fully developed tapeworm is merely a matter of growth. But the life history from the time the posterior segments containing the eggs pass out in the feces of the sheep is unknown. There is reason for thinking that the egg must be subsequently ingested by some intermediate host in which it develops to a larva capable of infecting the sheep with the tapeworm, but nothing is known about this.

FIG. 52.—The fringed tapeworm (*Thysanosoma actinioides*). Natural size. (From Bureau of Animal Industry Bulletin 4.)

Contrary to the usual custom with adult tapeworms, this worm inhabits not only the small intestine of the sheep but also the bile ducts and the gall bladder, and occasionally the pancreatic ducts. This obstruction of the bile ducts deranges the liver and interferes with digestion. Digestion is further interfered with by the obstruction and irritation due to the parasites in the intestine. This interference with digestion results in the host animal becoming thin and enfeebled, and sets up a train of nervous symptoms which naturally follow malnutrition and indigestion. These nervous symptoms are aggravated by the visceral irritation due to the attachment and movement of the tapeworms. The disease needs more study, but there seems to be little room for doubting the conclusions of Curtice (1890 *c*), who says:

> Sheep do not die from the tapeworm disease alone * * * The majority may die during cold storms, either from freezing or from suffocation while piling upon each other for warmth. They may starve to death either from inability or lack of desire to eat. They may die from other diseases. The tapeworm disease appears to render them more liable to other affections and less able to withstand the inclement season. It is therefore indirectly chargeable with the loss. Even if the infected sheep do not die, the parasite is still a cause of pecuniary loss. The impoverished condition traceable to it is a small average loss for each animal, but for flocks of over 5,000 sheep the aggregate is thousands of dollars for each ranchman.

As the map (fig. 53) shows, this worm is essentially a parasite of western sheep. Although the data are not evident for demonstrating the fact, it is probable that the infected area includes practically all the States west of the Mississippi River, and that practically all the States east of the Mississippi are uninfected. The reason for this distribution is not evident at the present time, but it will probably be clear when the life history of the worm becomes known. There is a possiblity that an intermediate host necessary in the life history of the worm has a corresponding distribution. The States which the available records

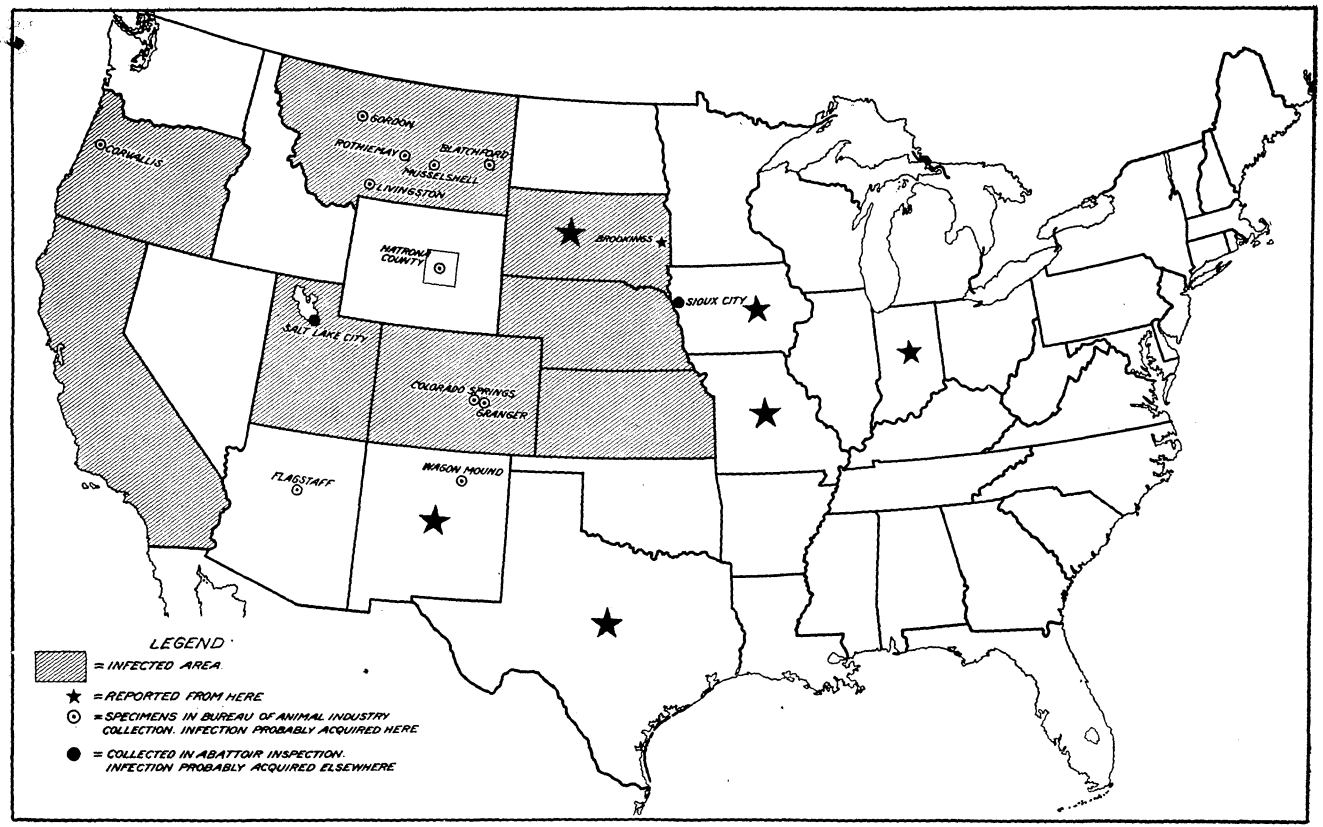

FIG. 53.—Map showing infection with the fringed tapeworm (*Thysanosoma actinioides*).

warrant us in labeling as infected are Oregon, California, Montana, Utah, Colorado, South Dakota, Nebraska, and Kansas. In the same part of the country the parasite has been recorded from Arizona, Wyoming, New Mexico, Texas, Iowa, and Missouri, and it is probable that these States and the Western States from which we have no records (Washington, Idaho, Nevada, and North Dakota) are all infected to some extent.

In this connection it should be borne in mind that a lack of records is not evidence. Had anyone ever made an investigation and found no evidence of this parasite in the States from which we have no records, it would be evidence, even though negative in character, and we would be warranted in drawing certain restricted conclusions from such evidence. But where a State is more or less surrounded by infected territory and there is no evidence that the infection has been looked for in that State, that alone is sufficient to warrant a suspicion, all other things being equal, that the infection exists in that State.

East of the Mississippi the parasite has been recorded from Indiana. There is no evidence back of the record to show whether the parasite has a foothold in this State, although Craig and Bitting (1903) claim, as noted below, that Indiana sheep have acquired the disease.

This parasite is a native of North and South America. It was first collected in Brazil in 1824. Curtice (1890 c) says that an identification of *Tænia plicata* from Missouri sheep in 1875, in a reference which I am unable to verify, leads him to suspect the presence of *Thysanosoma actinioides* in Missouri sheep. The next record from this country undoubtedly refers to the fringed tapeworm of sheep. The reference is to the report of the veterinary department of the State Agricultural College of Colorado for 1884, and is cited by Curtice in the article just noted. I am unable to verify the reference, but the quotations given by Curtice show that what Dr. Faville calls *Tænia expansa*, in the report referred to, is undoubtedly *Thysanosoma actinioides*. Four years later McEachran (1888), in recording tapeworms from the liver of Colorado sheep, has adopted the name used by Dr. Faville.

Of this parasite Curtice (1890 c) says: "The fringed tapeworm is at present the most common parasite of the sheep of our western plains, and causes by far the greatest loss of any intestinal parasite in this country." In an article apparently by Fischer (1899), from the Kansas Agricultural Experiment Station, it is stated that "this is one of the common intestinal worms affecting western sheep, and causes by far the greatest loss of any parasite affecting this animal in this and adjoining States."

Craig and Bitting (1903), writing from Indiana, state:

> The parasite is not of much consequence in this State, except as it is brought in with feeding stock. Whole carloads of sheep brought from St. Louis and

Chicago have suffered from the affection, and as high as 60 per cent have died. In some few cases the disease has been communicated to the home-grown sheep; but, as a rule, recognition of trouble has been so early, or the flock kept intact until reshipped, so that little spreading has occurred.

In this connection it is interesting to note the statement of Niles (1897), who says: "As far as our observation goes, it is not a common parasite in native Iowa sheep, but the importation of western sheep is likely to introduce it to a greater or less extent."

Of Missouri, Luckey (1908) says: "It is apparently not very common in this State, as only a few reports have been received concerning it." Dr. M. E. Knowles, the State veterinarian of Montana, tells the writer that he thinks the parasite does $100,000 worth of damage a year in Montana. Moore (1903), writing from South Dakota, says: "In our own State it is quite generally distributed. * * * The largest infestation found was 75 distinct worms in one animal. The greatest mortality recorded from one flock was 25 per cent."

Curtice (1889 and 1890 c), whose work on this parasite, done in 1886 and 1887, is still the best summary of our knowledge, says that post-mortem examination of Colorado sheep indicates that 80 to 95 per cent of the sheep in the flocks are infected. He found as many as 100 tapeworms in one sheep. He says that this tapeworm—

is at present the most common parasite of the sheep of our western plains, and causes by far the greatest loss of any intestinal parasite in this country. * * *. The influence on the life and health of its host is not inconsiderable. The ultimate loss is seen when lambs which should be strong and fat are not, and die during the colder weather while the fatter ones survive. This loss * * * can not perhaps be accurately estimated, but is nevertheless present, for thin, hide-bound, dwarfed sheep are not valuable for mutton, nor do they produce as much wool as they otherwise would.

He notes that the sheep are undersized, hidebound, have a rheumatic gait, have difficulty in cropping short grass, act foolish, do not seem to see well, and stay at the rear of the flock. He says:

I think it alone is responsible for more losses than any other sheep diseases on the prairies excepting scab. The direct death rate traceable to it is large when compared to the entire death rate, and the indirect loss traceable to it is, though more insidious in its character, still larger, for it is ever present and ever active.

The disease due to the fringed tapeworm is so largely complicated by other diseases, such as loco disease, that it is difficult to say at this time just what the symptoms of the disease and the loss due to it are. It is certain that it is the cause of considerable loss, and that this loss will not be greatly lessened, in all probability, till we know more about the life history of the worm.

Hæmonchus contortus.

This parasite, often written of under the old name of *Strongylus contortus*, is known as the stomach worm, not because it is the only

worm parasitic in the stomach of sheep and cattle, but because it is the most important and the most widely distributed. It occurs in the fourth stomach, the place where the hay and other coarse vegetable food of the host animal has finally become converted into chyme, and where the worm can do the most damage in irritation to the mucous membrane and in absorbing food that should be utilized by the host animal.

The male *Hæmonchus contortus* (fig. 54) attains a length of three-fourths of an inch (20 millimeters), and has at the posterior end a clasping organ, known as a bursa, which has a very characteristic bilobed structure. The female (fig. 54) may attain a length of 1¼ inches (30 millimeters), and is characterized by a spiral striping due to the coiling of the two uterine branches around the intestine. The worms are red.

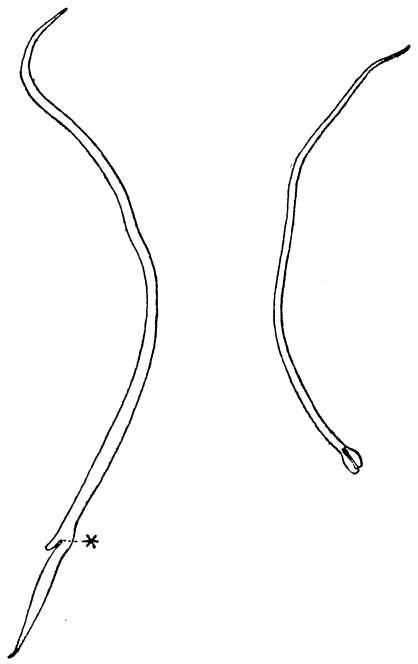

FIG. 54.—The stomach worm (*Hæmonchus contortus*). Enlarged. * Vulva. (From Bureau of Animal Industry Bulletin 127.)

The stomach worm has a simple life history, which was first worked out in detail by Ransom (1906 i). The female produces large numbers of eggs, which are passed in the feces of the host animal. These eggs hatch in two days if the temperature and moisture conditions are favorable, and small embryos, in what is known as the rhabditiform stage, escape. These begin feeding and growing, the skin being molted in the process at least once. The embryo is then in the sheathed stage, its former cuticle completely encasing it. Embryos attain this stage in about 10 to 14 days. The embryo is now sealed up and no longer feeds. Previous to this time the eggs and embryos are easily killed by drying and exposure to low temperatures. After becoming ensheathed, the embryos are very resistant to these conditions. During wet weather and while the dew is on the grass the embryos crawl up the blades of grass, and sheep or cattle eating the grass take the embryos into the stomach where they develop into the adult worms.

The presence of these worms in the stomach results in the irritation of the mucous membranes, causing disturbances of digestion and resulting malnutrition. Moreover, the worm is a bloodsucker by

virtue of the hook structure in the mouth. This bloodsucking habit results in anemia in the host animal. From these things the sheep become feeble and thin. Some of them die from heavy infections. Others are so enfeebled that when they have to undergo some unusual and adverse experience they are unable to stand the extra strain and perish.

So far the records indicate that the area infected with this parasite to the point where it constitutes an actual menace to the flocks is confined to the Eastern and Middle Western States. (See fig. 55.) The life history of the worm is so simple and its development is so direct that it is probable that the parasite is distributed all over the United States wherever there is moisture enough to permit of the hatching of the egg and the development of the embryo. It is likely that the dryness of the western plains is the factor which has limited the infection with this worm to the point where it has been utterly subordinate to the infection with the fringed tapeworm. A parasite which returns to its primary host in its drinking water has a very fair chance of getting into the water where the host drinks from a puddle on the plains. But one like the stomach worm, which is adapted to crawling up on blades of grass in the dew, is much less certain to infect its host on the western plains than in the Mississippi Valley or along the Allegheny Mountains or Atlantic coast region.

The fact that the writer finds no records to indicate that certain New England or Southern States are infected is perhaps due to the comparative unimportance of the sheep and cattle industries in some of these States, and to lack of investigation in others.

This laboratory has specimens collected at Granger, Colo., as early as 1886, by Dr. Curtice. The fact that this parasite had established itself on the dry Colorado prairies at that early date shows how quickly and easily it gets a foothold. The writer has collected it in 1911 in Elbert and El Paso Counties, Colorado. The infection was usually light, the heaviest infection being 537 worms in a 3-months-old lamb. The 1911 records from Colorado are not shown on the map.

Dalrymple (1903) says of the lamb diseases in Louisiana: "We are of the opinion that * * * stomach-worm disease is responsible for a large percentage of the mortality." Luckey (1908) says that it is reported from all parts of Missouri, the percentage of loss, especially among lambs, often being very high. Stiles (1902 a) found this parasite in about one-third of the cattle he examined in an outbreak of verminous diseases in Texas. The losses from this and other worms in mixed infections amounted to 50 per cent in two herds, and a total of at least 10,000 cattle for the year. Some years earlier Detmers (1883) stated that this worm and the lung worm do

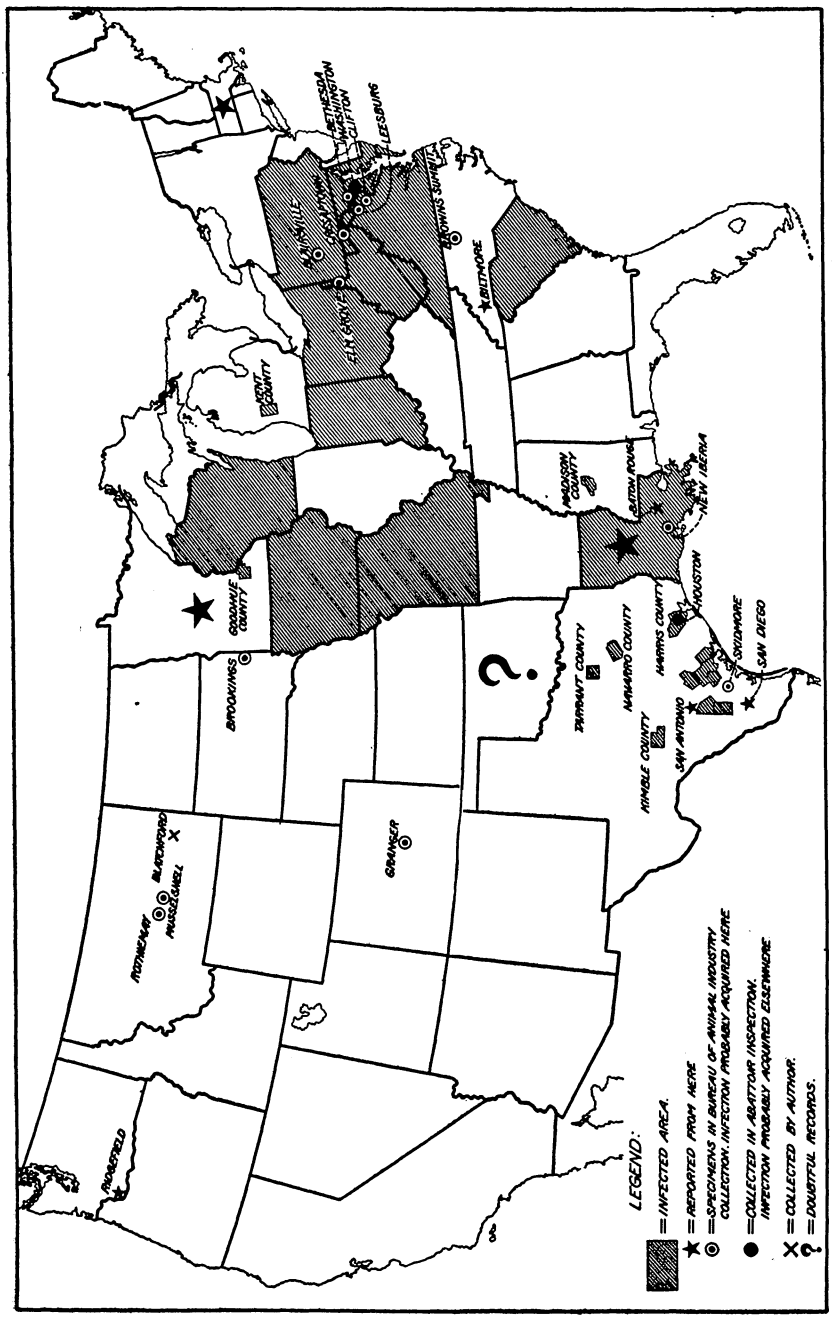

FIG. 55.—Map showing infection with the stomach worm (*Hæmonchus contortus*.).

more damage in Texas than fluke or tapeworm parasites. He states that it causes gastric trouble, emaciation, anemia, and not seldom death. While the Spanish term "lombriz" is sometimes used to denote any verminous infection, he states that the term is restricted properly and commonly to the stomach-worm disease. Detmers saw specimens of the stomach worm taken from a sheep near San Antonio in 1881, which is still further evidence of the early and wide distribution of the parasite in this country.

Spencer (1901) states that in late summer and early fall this worm causes considerable loss in Virginia. Smyth and Niles (1896) say: "In Virginia more sheep are lost annually as a result of intestinal parasites than from all other diseases combined. * * * *Strongylus contortus* * * * and *Œsophagostoma columbianum* are the most common in this State." Of West Virginia, Stewart and Atwood (1903) say: "Stomach worms * * * seriously interfere with successful sheep husbandry in this and other sections of the country." Wheeler (1903) notes that in North Carolina 66 of the Biltmore flock of Southdowns and Southdown grades were killed by this parasite in six months. This parasite and nodular worm were found to be responsible for loss of sheep at Brown Summit, in North Carolina, by Dr. Graybill of this laboratory. In South Carolina, Klein (1905) says the disease prevails quite extensively and causes many deaths. Phares (1889) has recorded the stomach worm from Mississippi.

Paige (1906) says this parasite was not recognized in Massachusetts prior to 1902, but was found in sheep and goats that year. During the four succeeding years six flocks ranging from 20 to 150 in number had been observed and had lost from a few animals to the entire flock as a result of stomach-worm disease. Lewis (1902) implies that this parasite occurs in Oklahoma, but does not definitely say so.

The Middle West has suffered considerable loss from the stomach worm. In Ohio, Wing (1898) states that it "is undoubtedly responsible for most of the deaths among our lambs." Mr. Wing has since made every effort to arouse interest in this parasite. From Indiana, Craig and Bitting (1903) write:

> From an economical standpoint, it is the most important of all the parasites in this State. Probably the average annual loss that may be attributed to this cause will be about 30,000 head. The parasite is to be found in greater or less numbers in nearly all flocks.

Of Iowa, Niles (1897) says:

> In this State the stomach worm has caused more or less trouble for several years, and during the past two years serious losses have occurred in many sections of the State. During the past season this trouble has been reported from many counties and in many flocks the fatality has been very high. It is safe to say that during the year 1896, the stomach worm caused greater loss in Iowa than all other sheep affections combined. One breeder reports losing 55 lambs out

of a flock of 180; another 40 out of 100; another 24 out of 45; another 105 out of 135; another 40 out of 50. Many others reported heavy losses. It seems evident from the increased number of diseased flocks reported from year to year that this parasite is rapidly becoming more widely disseminated among our flocks. This matter is easily explained, for many of those engaged in breeding fine sheep have lost heavily, and animals purchased from these flocks have served to contaminate others.

The report of the Minnesota State live-stock sanitary board for 1908 states: "Stomach worms of sheep have caused more or less loss to flock owners." Hopkins (1900), writing of Wisconsin, reports that it causes losses of 15 to 60 per cent, one farmer losing 180 out of 400 in spite of worm medicines. Marshall (1910) reports losses from Kent County, Mich.

The writer has already cited cases where the number of stomach worms found by him in sheep examined at this laboratory in connection with some of Dr. Ransom's experiments was as high as 3,915 in one case, and 4,350 in another. The worms were not actually counted, owing to the difficulty of doing anything of the sort, but the number of worms in a cubic centimeter was counted and this number multiplied by the number of cubic centimeters of worms present. Checking this method showed that it gave fairly accurate results. It gives data that are much more satisfactory than a statement to the effect that post-mortem examination disclosed hundreds or thousands of worms. It can readily be seen that something like 4,000 worms would abstract quite a large amount of food material and blood from the host. It is further believed that these worms secrete a toxin which exerts its poisonous effect upon the host animal, and the amount secreted by so many worms must be considerable.

Œsophagostomum columbianum.

This parasite, commonly known as the nodular worm, from the intestinal nodules caused by it, and the nodular disease itself were first described by Curtice (1890 c). He notes that the disease, commonly known as "knotty guts," had previously been observed in the South by Dr. Salmon, and that Dr. Theobald Smith had made some investigation of it in the winter of 1886–87. The adult worms live in the upper part of the large intestine of the sheep, or, according to some writers, in cattle. Ransom (1911) states that in all cases examined by him the nodular worm of cattle was found to be another species. The female worm attains a length of about five-eighths of an inch (15 millimeters), the male being a little shorter (see fig. 56). The worms have a characteristic solid white color which differentiates them from most of the other sheep parasites, which are somewhat translucent, yellowish, or, in the case of the stomach worm, red, The head is bent over and forms a hook with

the body. The parasite appears to be a native of this country which has adapted itself to our sheep.

The life history of this worm is not completely known. The eggs produced by the females are passed with the feces of the host. When the resulting embryos again come to light they are found in tumors in the mucous lining of the intestine. Here they form cysts which become surrounded by necrotic material due to the resulting inflammation. (See Pl. XXXVI, fig. 2.) The cysts break down and the embryos live in the necrotic mass. After a time they break from the tumors and attain maturity in the lumen of the intestine. It appears that the formation of tumors may not be essential to the development of the worm, and perhaps the stage in the intestinal mucosa is entirely omitted at times. The writer in one instance found 29 nodular worms in the intestines and only 1 nodule visible. This might be taken to indicate that nodule formation is not essential but only incidental to the development of the worm. Curtice (1890 c) has made similar observations, and surmises that this species develops normally in the lumen of the intestines; that some embryos penetrate the walls of the intestines and even get to the mesenteric glands, the liver, or the omentum; that those which penetrate the wall of the intestines may develop slowly and at length get to the lumen of the intestine, or may die; that this tumor-making stage of the life history may favor the survival of the species by providing slowly developing forms which pass the winter here and mature in spring at a time when the eggs spread on the pastures will better serve the purposes of infection; and that worms penetrating the walls of the intestines too deeply, such as those attaining the omentum or the liver, perish. On the other hand, there is a possibility which Dr. Ransom has suggested to the writer, that the embryos normally penetrate the intestinal walls, and in the course of their development give rise to lesions which are so small as to be readily overlooked in the course of macroscopic examination, and which heal promptly on the escape of the worm. The formation of the large nodule would only follow, then, in the case of embryos which penetrate too deeply, as Dr. Curtice suggests, or perhaps when complicated by the action of bacteria.

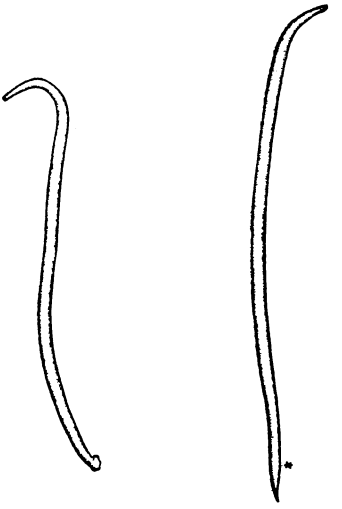

FIG. 56.—The nodular worm (*Œsophagostomum columbianum*). Enlarged. * Vulva. (From Bureau of Animal Industry Bulletin 127.)

As an economic factor, this parasite is confined to the Eastern, Southern, and Middle Western States. (See fig. 57.) There does not seem to be sufficient evidence available to warrant Dalrymple's (1904) statement that "there is hardly a State in the Union that can claim freedom from it among its flocks." The writer has never seen a case in the examination of hundreds of Colorado sheep, and has not even found it recorded from west of Minnesota in the north and Texas in the south, although this is more likely to be due to the parasite being uncommon in such States as Kansas rather than to its being absent, as it seems unlikely that a parasite with a simple life history would fail to infect at least some small areas in the general east and west shipments of sheep for feeding, breeding, or slaughter. It seems true, however, that the western plains and the Pacific coast are so free from this worm that they may be declared uninfected. In the writer's opinion, the Southern and Eastern States not shown to be infected on the map, with the possible exception of some New England States, are probably infected and we merely lack printed records, or perhaps investigation, to show this.

Curtice (1890 c) says of this parasite:

> Dr. D. E. Salmon, Chief of the Bureau of Animal Industry, who at one time lived in the South, performed many post-mortem examinations on diseased sheep, and found nothing but these intestinal tumors to account for the severe symptoms of disease which they exhibited, and has verbally stated that he believes this malady is the chief obstacle to successful sheep husbandry in some portions of the Southern States. * * * Dr. Salmon believes that the disease may bring death to its victims in the severest cases. My own observations have been confined to the abattoirs, where saleable animals only are brought. * * * The most seriously affected sheep found in the abattoirs are noticeably poorer, and one would be tempted to believe, were he to judge from the "knotty" viscera, * * * that such animals should have died from the disease long before. These sheep usually have diarrhea, a disease which weakens the affected animals.

These early conclusions of Curtice's as to the injuriousness and importance of the disease have been confirmed and strengthened by later workers. Of Virginia, Smyth and Niles (1896) say:

> This parasite is exceedingly common in this State. In fact, it is quite difficult to find a sheep which is entirely free from it. * * * The writer * * * has met with instances in which over half of large flocks of sheep have been lost as a result of this worm.

Dalrymple (1901) says:

> It appears to be quite prevalent throughout the South, and at times very few sheep are butchered that are entirely free from this knotty condition of the bowels, which renders the intestines unfit for sausage casings.

Dalrymple has published a number of studies of the "bare-lot" method of eradication. As already noted, Dr. Graybill has found this parasite and the stomach worm causing losses among lambs at

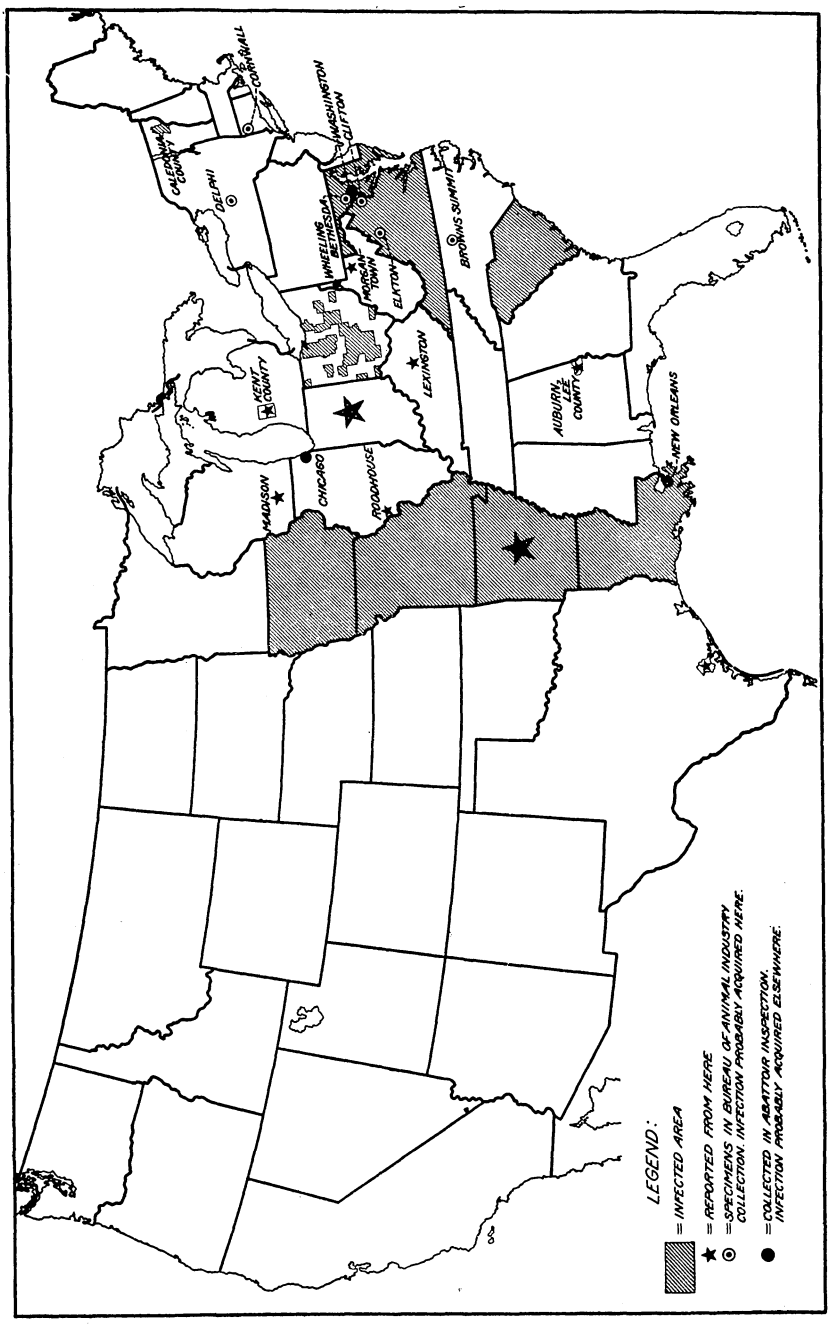

FIG. 57.—Map showing infection with the nodular worm (*Œsophagostomum columbianum*).

Browns Summit, N. C., in 1909. He has also found it near Wheeling, W. Va., in 1908, and at Auburn, Ala., in 1907. The findings in the last case have been published by Giltner (1908).

The parasite appears to be spreading in the Middle West. Craig and Bitting (1903) indicate the presence of nodular disease in Indiana, and say: "This peculiar disease has not been known for very many years and seems to be gaining its foothold quite rapidly." The live-stock commissioners of Ohio in their report for 1904 made their first mention of the disease, as follows: "The disease occurs only in a few localities in this State. In the past year one outbreak was observed near Lockburn." The following year, 1905, they reported:

> Not many years ago nodular disease in sheep was unknown in Ohio; it is now reported more frequently from year to year and is becoming very destructive to sheep in several sections of the State. * * * The disease frequently terminates in death, and in other cases it permanently affects the general health of the animal. Once introduced on a farm, it is a difficult matter to exterminate it. Its treatment is very unsatisfactory. * * * The best preventative is the observation of care in the purchase of new stock. Farms free from the disease should not be stocked with sheep from the infected areas.

This last point is one which the writer has already emphasized in connection with the desirability of a knowledge of the distribution of parasites. The commission printed a map showing that 7 counties were infected. The report for the next year showed 13 counties infected, the next year 15, the next 25, the next 26, and their last report, published in 1910, showed 29. In this report they say:

> Twenty years ago this disease was unknown in Ohio. To-day it is common in 29 counties, and probably present to some extent in every county where sheep are raised. The losses from this disease are probably as serious as those from tuberculosis in cattle. We know very little about effective remedies for the trouble. Once a pasture has become infected, sheep should be kept off for several years until the worm parasites die out. A few thousand dollars spent in the investigation of remedies for this trouble would be a paying investment for the State.

The work of this commission in mapping the infected areas in the State of Ohio is a model which it would pay other States to copy.

Niles (1897) refers to this disease in Iowa as follows:

> In this State it is very rare to find a sheep over 8 months of age that does not show some indications of the trouble. * * * In a number of instances where serious loss has occurred in flocks in different parts of the State, no other cause of death could be discovered. * * * When the affection does not produce a fatal termination, the loss from unthriftiness, partial failure of the wool crop, and the rendering of the intestines unfit for sausage casings, is by no means trivial.

The parasite is recorded from West Virginia by Stewart and Atwood (1903), from South Carolina by Klein (1906), from Wisconsin by Hopkins (1900), from Michigan by Marshall (1910), from Vermont by the State Board of Agriculture of Vermont (see Bell,

1900), from Arkansas by Dinwiddie (1892 b), and from Texas by Stiles (1902 a). Dr. Luckey writes me under date of March 2, 1911: "It is not uncommon in any part of the State (Missouri) to find *Œsophagostomum columbianum* in either sheep or cattle."

Œstrus ovis.

The sheep gadfly (fig. 58, *a*) is seldom seen in the adult stage by the sheepman. Riley (1869) describes it as looking "something like an overgrown house fly." It has no mouth and hence does not feed, the principal purpose of the animal at this stage being that of reproduction. After the mating of the male and female flies, the female deposits its larvæ, already hatched from the eggs, inside the nostril of the sheep. The larvæ are provided with hooks, and by means of these they work their way up into the nostril of the sheep. The larvæ develop into grubs, which attain a length of three-fourths of an inch (20 millimeters) (fig. 58, *b*). The larvæ are first white, but later become yellow, and finally a dark yellow with a black band on each segment, and the segments armed with black spines. This is the stage in which the parasite is most commonly seen and described. At the proper time this grub escapes from the nostrils, falls to the ground, and bores its way underground to a depth of 1 or 2 inches. After a period, which varies with the weather conditions, the mature fly emerges from its pupal case and makes its way to the open air.

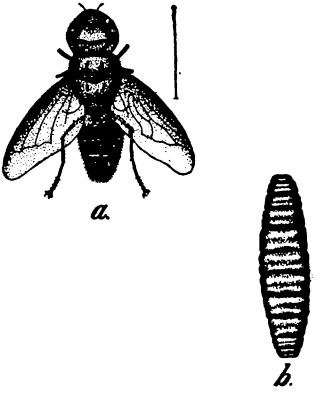

FIG. 58.—The sheep gadfly (*Œstrus ovis*). *a*, Adult fly. (After Brauer.) *b*, Larva or grub from nose of sheep. Enlarged. (After Curtice.)

As the larvæ crawl around over the sensitive mucous membrane of the sheep's nostrils, they cause considerable irritation. This results especially from the sharp spines on the ventral surface, which cause minute hemorrhages where they puncture the mucosa. The grubs work their way back to the passages of the turbinated bones and into the frontal sinuses. Curtice (1890 c) states that some of them become entrapped among the windings of the superior turbinated bones and in the orifice leading to the superior maxillary sinus, the grub increasing in size to the point where it is unable to return by the passage it entered as a smaller larva. The irritation caused by the grubs causes a catarrh, from which the disease due to the grub takes the name of "snotty nose." Worse than this is the fact that the inflammation set up in the nasal mucosa causes an irritation of the nerves of smell, and the inflammation is trans-

mitted along the short course of these nerves to the brain. When the grubs are numerous the effects on the sheep are serious and at times fatal. The catarrh is accompanied by considerable sneezing and snorting. Later the animal shakes its head or rubs its nose on the ground. It walks with a peculiar gait, similar to that of some giddy sheep, but does not show the circling or the other repeated automatic actions of typical giddy sheep. The affected animal becomes emaciated and may die in convulsions. As a rule, it is able to survive the attack until the escape of the larvæ from the head, and then the symptoms abate and the animal recovers. Curtice (1890 c) states that the largest recorded number of grubs from the head of a sheep is 60 to 80.

It is still a moot point, and one on which positive evidence would be welcomed, as to whether the larvæ ever penetrate to the brain of the sheep. Riley (1869) states that according to reliable sheepmen the parasite may enter the brain. Curtice (1890 c) says: "The larvæ of the *Œstrus*, or the grubs, never do and never can penetrate into the brain." The former is an opinion commonly entertained by sheepmen. Both positions have been maintained by veterinarians. Quite recently, Blasi (1910) reports that in a post-mortem examination of a sheep he found a typical larva of *Œstrus ovis* in the right lateral ventricle. There was an eccentric dilatation of the ventricle, considerable augmentation of the cephalo-rachidian fluid, with amaurosis and lesions of the optic lobes and the neighboring regions.

Riley (1869) reported that this grub was present "in the head of almost every sheep that dies, in the Western States at least." This statement is presumably based on probabilities, in large part, rather than on actual observation or printed records. While it is probably true, it is nevertheless desirable that we have definite information on this point, and at the present time there are some States from which the writer has found no records. The existing records, showing the parasite on both coasts, along the Canadian border States and the Gulf, and through the interior, indicate that the distribution of the fly is in a general way coincident with the distribution of the sheep (see fig. 59). A study of this distribution might disclose exceptions which would be indicative of means for minimizing or avoiding infection.

Gordon (1883) quotes a sheepman in Monterey County, Cal., who says that "worms in the head" is the only fatal disease. This refers to the *Œstrus* larvæ, or "grub in the head," presumably. Riley (1869) refers to observations made by various persons in Illinois. Luckey (1908) says of Missouri, "there is probably no flock in the State entirely exempt from it." Gordon (1883) states that this disease is a source of limited loss in the State of Montana. The writer has been told by Dr. Ketchum, of this bureau, that at the St.

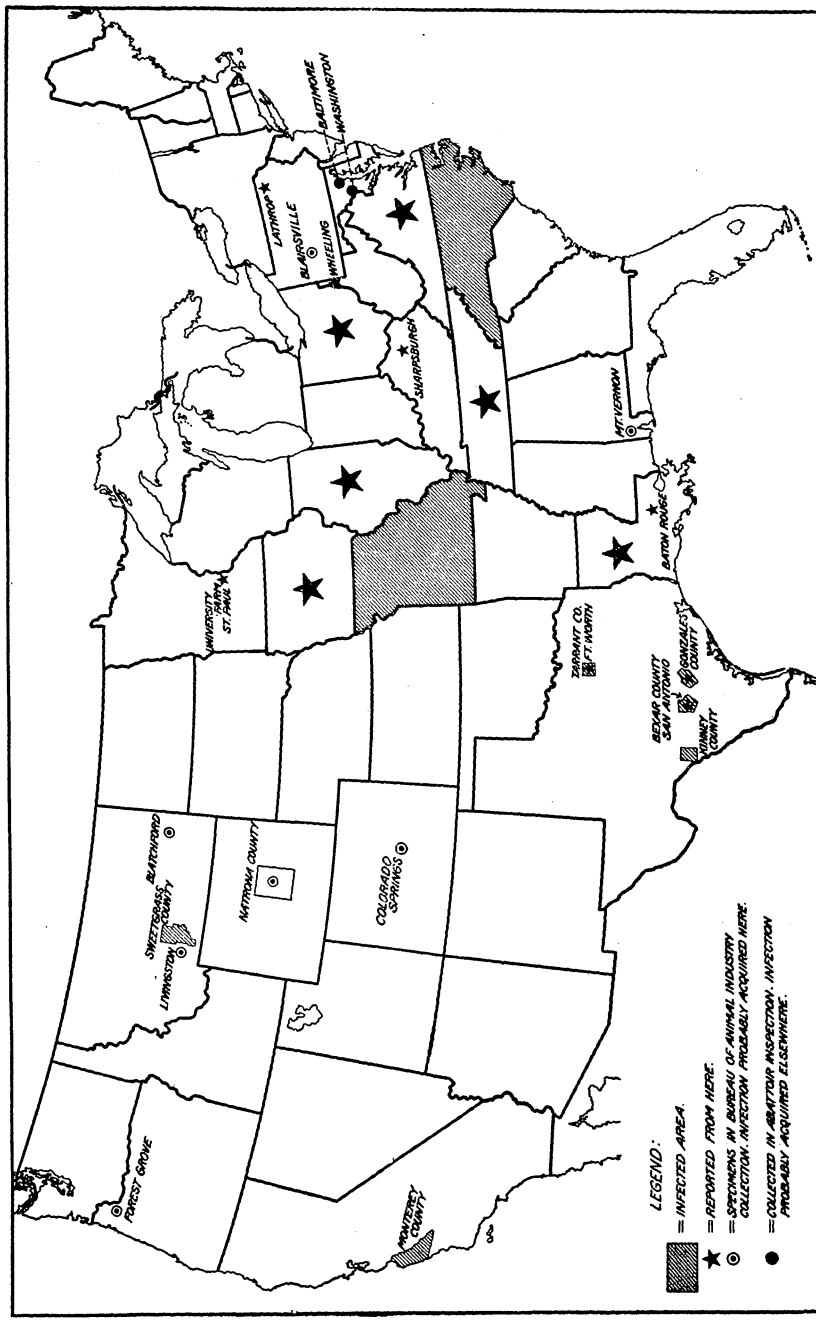

FIG. 59.—Map showing infection with the sheep gadfly (*Œstrus ovis*).

Paul abattoirs the degree of infection of sheep from Sweet Grass County, Mont., was notable, and sheepmen in this county assured the writer that "grub in the head" was perhaps their most serious pest. Butterfield (1900) found it in a flock of 125 sheep in Pennsylvania, and it appeared that this parasite had caused the death of 50 in this flock in three years. Riley (1869) implies the presence of the parasite in Tennessee. Of Texas, Gordon (1883) says, "One owner reports losses from grub in Kinney County," and Detmers (1883) says: "The only real drawback to sheep raising in Texas * * * is caused by the blowfly, and perhaps, also, though in a much less degree, by the gadfly, *Œstrus ovis*." Wing (1898), writing from Ohio, says: "'Grub in the head' has never, in my experience, done noticeable injury to the flock." Niles (1897) says: "The loss in Iowa caused by the sheep bot fly is not heavy." Wheeler (1895) records the death of 117 out of 239 sheep in one flock, and 200 out of 459 in another, where this parasite was the only apparent cause. The sheep had been shipped into Louisiana from Texas, and had apparently been infected in Texas. The fly seems to be plentiful in Louisiana, however, as Dalrymple (1903) says that he has extracted 42 larvæ from the head of one sheep, and thinks that this number is not the maximum for this State. The fly has been recorded from North Carolina by McCarthy (1896), and from Minnesota by Lugger (1896). Dr. Graybill has found it in sheep near Wheeling, W. Va., in 1908, and the writer has collected it this year (1911) in a sheep from Pluck, Va. Herrick (1899) leaves us in doubt as to Mississippi. The writer found about 10 to 20 per cent of the sheep infected in some flocks in Elbert and El Paso Counties, Colo., in 1911. The infection was light in all cases seen. These Colorado records are not shown on the map.

Psoroptes communis ovis.

The parasite which causes common sheep scab is a small mite (fig. 60) easily overlooked on the sheep, but readily visible to the naked eye when the mite is placed on a dark surface. According to Salmon and Stiles (1898), the life history of the parasites is substantially as follows:

The female mite lays about 15 to 24 eggs on the skin of the sheep, or fastened to the wool near the skin; six-legged larvæ are hatched; the larvæ cast their skin and become mature; the mites pair and the females lay their eggs, after which they die. The mites molt three or four times. They multiply with great rapidity, and Salmon and Stiles figure that with 15 days as an average for each generation of 10 females and 5 males the sixth generation would appear in three months' time, and would consist of about 1,000,000 females and 500,000 males.

FIG. 1.—A WELL-DEVELOPED CASE OF SHEEP SCAB DUE TO THE COMMON SCAB MITE (PSOROPTES COMMUNIS OVIS).

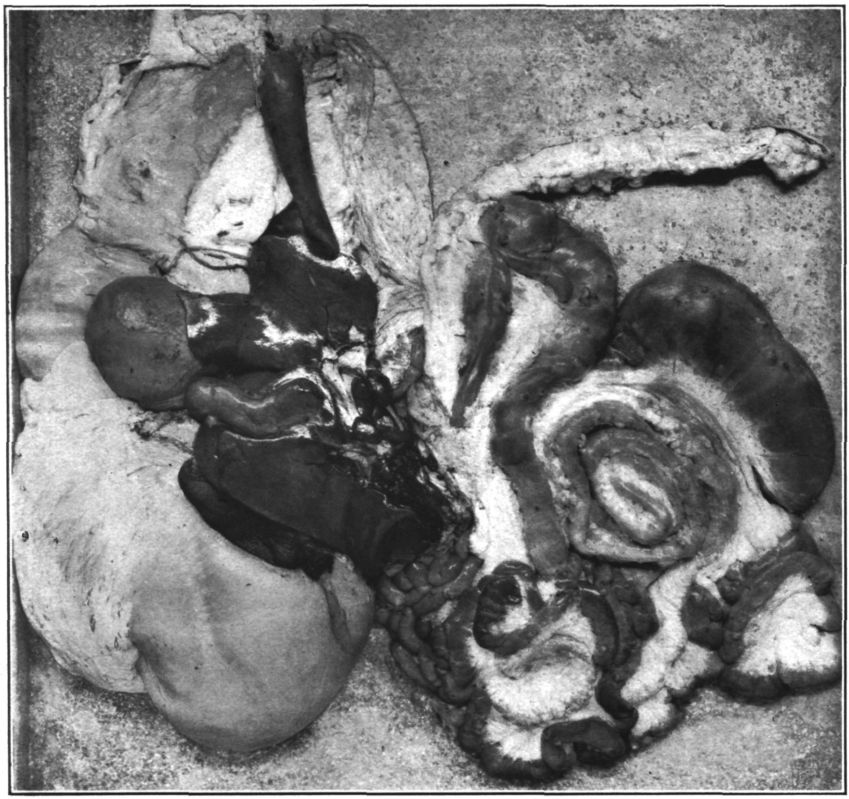

FIG. 2.—VISCERA OF SHEEP, SHOWING MODERATE INFECTION WITH NODULAR WORM (ŒSOPHAGOSTOMUM COLUMBIANUM). (ORIGINAL.)

The mites bite the skin of the sheep, and apparently introduce some irritating substance into the wound, for the bites cause intense itching, with irritation, formation of papules, inflammation, exudation of serum, and the formation of crusts or scabs. As the parasites multiply, they spread out along the edge of the scab and attack the healthy tissue there. Here is where they may be found most readily, only a few remaining in the scab or crust. The sheep become restless and scratch and bite themselves, or rub against other objects in order to relieve the itching. The wool becomes matted, and is pulled off with the crusts rubbed off by the sheep. (See Pl. XXXVI, fig. 1.) The skin becomes inflamed and thickened. In the course of 2 or 3 months the disease may have spread over the entire body.

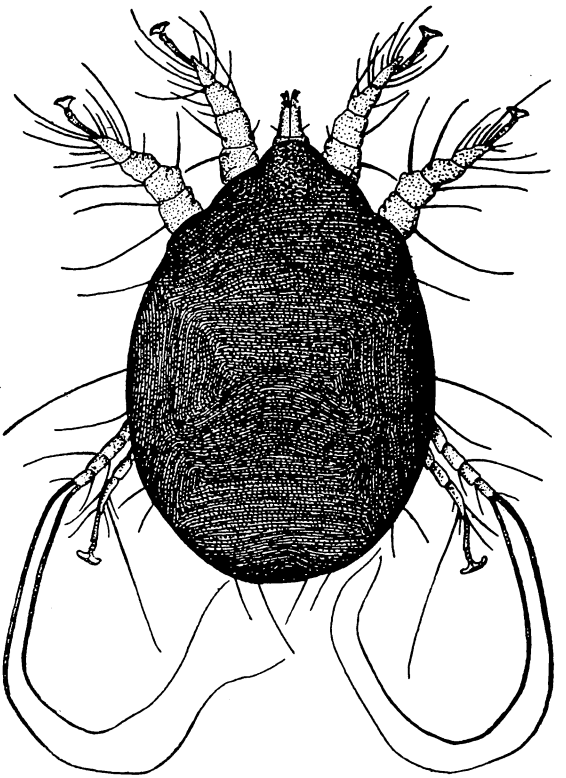

FIG. 60.—The common scab mite of sheep (*Psoroptes communis ovis*). Enlarged. (After Bureau of Animal Industry Bulletin 21.)

The disease is highly contagious, and cases may develop within a week after exposure to infection. It is spread by the infected sheep and by means of wool, scab, bedding, or anything that can carry the mites to another sheep. The infected sheep become anemic and emaciated. Unless treated for the disease they become more and more exhausted, and finally die, only a few making a spontaneous recovery. It is quite likely that the effect of the scab mite itself is complicated by the inoculation of streptococci or staphylococci incidental to the puncture of the skin by the mite, as has been found to be the case in demodectic mange of the dog.

This highly important disease results first of all in a loss of wool, a thing which insures the attention of the western sheepman, who commonly breeds for wool first of all. It does not even permit the

sheepman to save the pelt, that last saving which is looked after when western sheep die of almost any other disease or after the disastrous "pile ups" of winter storms. The unthrifty sheep ceases to be valuable as mutton. Finally, there is the loss from death, which Salmon and Stiles (1898) say amounts to from 10 to 80 per cent of the flock attacked.

Curtice (1890 c) says of scab:

> Of all the diseases of sheep in this country, scab is the most feared by the flockmaster. So insidious is its attack, so rapid its course, so destructive its effects, and so difficult is it to exterminate that it has justly earned the distinction of being more injurious than any other disease caused by external parasites. Scab alone, of the parasitic diseases, has become the subject of legislation in most countries, and yet, if proper precautions were taken and a rational treatment followed, this disease could soon be completely eradicated.

Salmon and Stiles (1898) say:

> Many persons engaged in the sheep industry have been forced to forsake it because of their losses from this disease. It is probable that in its destruction of invested capital sheep scab is second only to hog cholera among our animal diseases. * * * In addition to the direct losses in wool, in flesh, and in the lives of our sheep, we have suffered immensely in our foreign trade because of the prevalence of this disease.

Previous to the establishment of the Federal quarantine on scab, there was almost no place in the United States that could claim more than a temporary freedom from this disease. Such freedom was attained from time to time by some States as a result of the efforts of State officials, but it was difficult to prevent reinfection from adjacent States, and in those cases where the adjacent States were negligent or indifferent it meant that the effort to keep a State clean could never be relaxed until a general effort under the direction of the Federal Government should result in the eradication of the disease. The Western States were constantly infected for the most part. In this connection it is interesting to note that the writer has found a mite indistinguishable from the common scab mite of sheep, on a mountain sheep, *Ovis nelsoni*, according to Dr. Bailey, of the Biological Survey, which was suffering from scab in the National Zoological Park in Washington, D. C. This suggests that this animal may occasionally act as a carrier of the disease in some Western States. This seems more likely from a record of Warren (1910), who notes the death of 75 Colorado mountain sheep (*Ovis canadensis*) from scab contracted from domestic sheep.

The work against sheep scab is such an excellent example of what may be accomplished in combating a disease when its distribution is known and steps are taken to restrict and eradicate it, that the writer has indicated on the map (fig. 61) not only the present infected areas but also the areas formerly included within the Federal

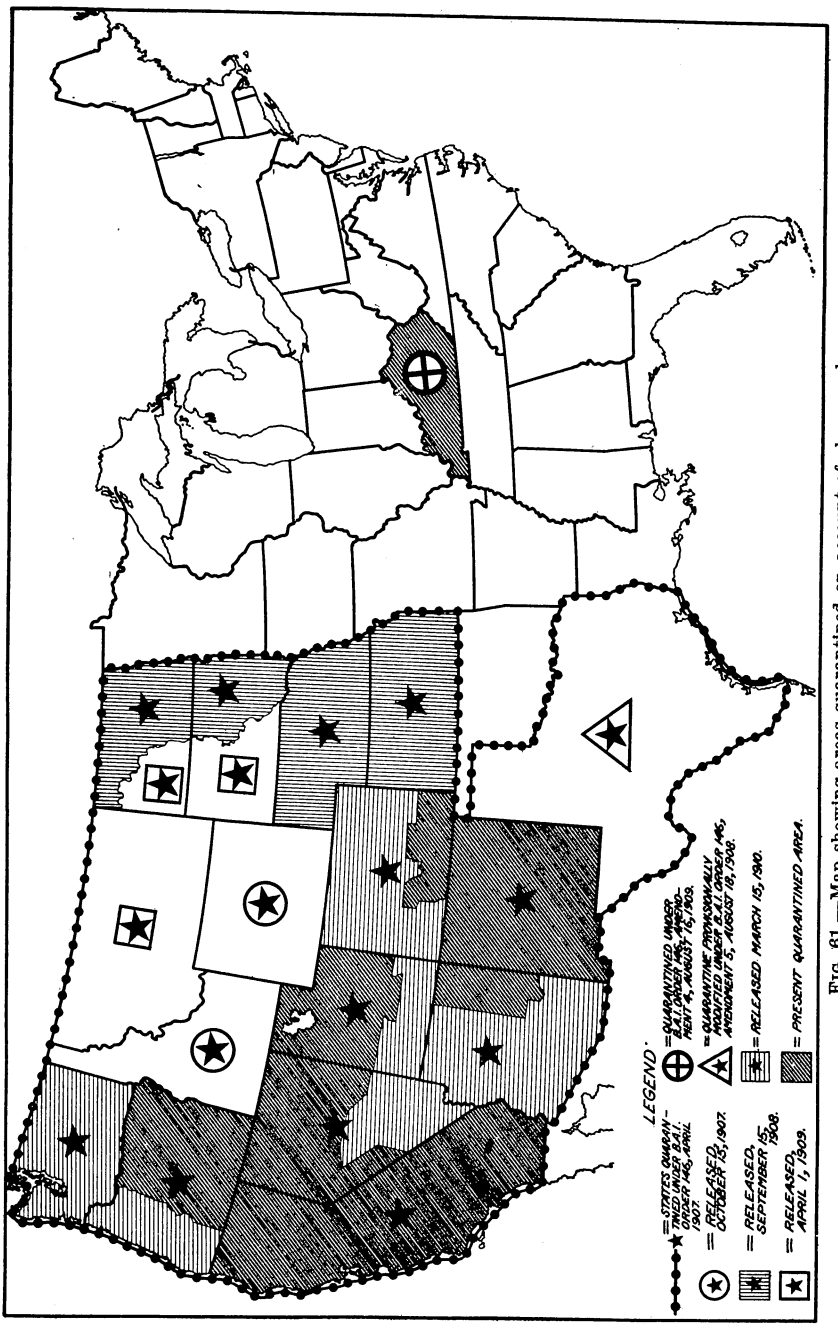

FIG. 61.—Map showing areas quarantined on account of sheep scab.

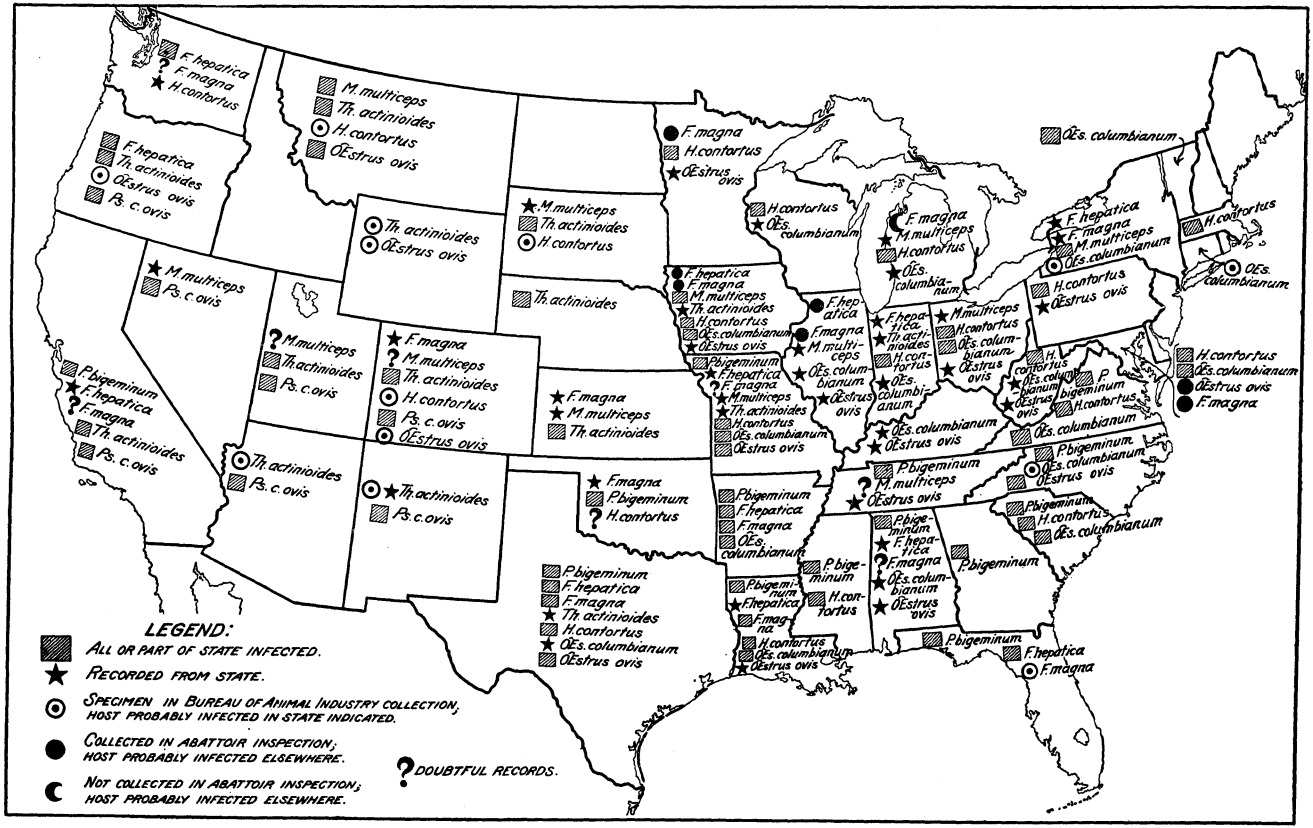

FIG. 62.—Map showing areas of reported infection with various parasites.

quarantine lines, with symbols to designate areas simultaneously released. The writer is informed by Dr. Steddom, Chief of the Inspection Division of this bureau, that other areas will presently be released. It is expected that ultimately the disease will be eradicated from the United States. The cost of eradication will be trifling compared with the loss saved.

FUTURE RECORDS.

A map (fig. 62) is published here which indicates for each State which of the parasites discussed in this paper have been recorded from that State, together with a symbol indicating the nature of the record. It is hoped that State and Federal employees, and also scientists and veterinary practitioners not in State or Federal employ, will add to this record wherever possible. The Bureau of Animal Industry will greatly appreciate such cooperation, and the information so obtained will in turn enable the bureau to furnish more exact information and more definite suggestions in regard to these parasites than would otherwise be the case.

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